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FACTORS AFFECTING LOCATION OF FIRMS

Numerous variables influence the location of individual firms as well as industries, which are aggregations of firms. The locational decision of a firm is important and complicated, and successful companies spend considerable time and effort in choosing the optimal location. Investments in inappropriate locations can be disastrous. Thus, a firm’s decision-making process is a rational, if imperfect, one and is subject to the iron laws of market competition. Although personal considerations such as climate or the owner’s residential preferences may occasionally be important for the margins, firms cannot choose arbitrarily or they will be forced out of business by their more rational competitors. The major factors of production that shape firms’ locations include labor, land, capital, and managerial and technical skills. (Others, such as transport costs, are considered in other encyclopedia entries.) All these topics are necessary for production and distribution, and all exhibit spatial variations in both quantity and quality.

Labor

For most industries, labor is the most important determinant of location, especially at the regional, national, and global scales. When firms make location decisions, they often begin by examining the geography of labor availability, productivity, and skills. The degree to which firms rely on labor, however, varies considerably among different sectors of the economy and even among different firms, which may adopt different production techniques.

The relative importance of labor varies considerably among industries. The demand for labor depends on the size of the firm involved and how labor intensive or capital intensive a given production process is, as well as the cost. In very capital intensive industries (e.g., petroleum), labor costs may be irrelevant. Thus, it is a mistake, but a common one, to assume that all industries seek out low-cost labor. Over time, most industries have become increasingly capital intensive; that is, they have substituted capital for labor, particularly when production in large quantities justifies the investments involved.

The supply of labor in a given region greatly affects the cost. In countries with high birth rates, the supply tends to be relatively high, and labor costs are low. In economically advanced countries, the birth rate is low, and labor is relatively expensive. Because some firms demand particular types of workers in terms of their age or sex, the demographic structure of a region also shapes the supply of certain types of employees (e.g., teenagers). Finally, since labor is mobile over space (but not perfectly so), migration (or internationally, immigration) also shapes the supply of labor.
FACTORS AFFECTING LOCATION OF FIRMS

In regions that can attract labor easily, wage rates will tend to be low, all else constant. When the supply is limited by, say, immigration restrictions, wage rates tend to go up. At the local level, housing costs can also constrain the supply of labor if they are so high that workers cannot find affordable places to live.

Under capitalism, the real cost of labor is determined by the relative productivity of labor rather than simply the cost of wages and fringe benefits. Thus, cost is hardly the only dimension concerning labor. Productivity is largely a function of the skills present in the local labor force, or human capital, which in turn are derived from formal and informal educational systems, on-the-job training, and years of experience. Firms will pay relatively high wages for skilled, productive labor. Consider that if labor costs were central to the location of all firms, then very low-wage countries, say Mozambique, should attract vast quantities of capital, which they don’t, and high-wage countries, such as Germany or the United States, should see a rapid exodus of jobs. The reality of the geography of labor is much more complex and involves labor markets in which jobs are constantly created and destroyed; skills are produced, reproduced, and change; and new technologies come into play, in addition to other cultural, economic, and social forces.

Moreover, the skill level of a given occupation greatly affects the size of its labor market. Generally, skilled labor markets tend to be geographically larger than unskilled ones. Workers may migrate long distances for well-paying positions, and the market for many skilled jobs is global in reach. Unskilled positions, in contrast, typically draw from a relatively small labor shed; few people would travel cross-country, for example, to take a job as a janitor or retail trade cashier.

The labor process is saturated with politics. Labor is the only “factor input” that is able to resist the conditions of exploitation, to go on strike, to engage in slowdowns or sabotage, or to unionize. Unionization rates vary widely, adding to differentials in the cost of labor. Thus, in addition to the cost of labor, firms must consider the length of the workday, the working conditions, health and safety standards, pensions and health benefits, vacations and holidays, demands for worker training, subsidized housing, and the role of labor unions, all of which shape wage rates and productivity levels.

Land

At the local scale (i.e., within a particular metropolitan commuting area, in which labor costs for a given occupation are relatively constant), land availability and cost are the single most important locational factors affecting firms’ location decisions. The cost of land reflects the supply and demand, and different types of firms require different quantities in the production process. Generally, larger firms, particularly in manufacturing, require more land and are thus more sensitive to the costs, although in some sectors, such

Employees attend a class at the training center of the sprawling corporate campus of Infosys Technologies in Mysore, India, in this January 31, 2007, file photo. Source: AP Photo/Gurinder Osan, File.
as producer services, firms pay very high costs (in rent or by purchasing a site). Firms often engage in intensive examination of several selected possible sites before settling on an optimum location.

The cost of land is heavily influenced by its accessibility. Transport costs determine the location rent of parcels at different distances from the city. Thus, because land downtown is the most accessible, it is by far the most expensive; in most cities, land costs decline exponentially away from the city center. However, not all firms necessarily seek out low-cost land. The imperative to do so depends on the trade-off between land and transportation costs that firms make to maximize their profits. Firms that must have accessible land—generally labor-intensive firms that must maximize their accessibility to labor, to each other, and to urban services—will pay very high rents to locate near the city center. Firms that do not require access to clients, suppliers, and services, on the other hand—such as large manufacturing firms in suburban industrial parks—make a different trade-off, choosing to locate on the urban periphery, where land costs are low but transport costs are higher.

Since World War II, there has been a centrifugal drift of manufacturing to suburban properties. Large parcels of industrialized land are more likely to be available in the suburbs than in central-city locations, where accessibility makes land relatively expensive. More reasons why industrial properties have expanded into the suburbs include these locations being easily accessible to motor freight by interstate highway, and access to suburban services and infrastructure, including ample sewer, water, parking, and electricity. Industries may also be attracted to the suburbs because of nearness to amenities and residential neighborhoods. Suburban locations minimize labor’s journey to work.

**Capital**

Under capitalism, capital plays a major role in structuring the production process. There are a variety of contexts in which the term *capital* is used, such as “natural capital” (i.e., climate and resources) or “human capital” (i.e., skills). In most economic geography, capital takes one of two major forms: fixed capital and liquid, or variable, capital. Fixed capital includes machinery, equipment, and plant buildings. Besides the installation and construction costs, firms must budget for maintenance and repair, and depreciation. The age of the capital stock of a region greatly affects its overall productivity levels. Liquid capital includes intangible revenues, including corporate profits, savings, loans, stocks, bonds, and other financial instruments. The rate of capital formation reflects variables such as corporate profitability (including market prices, production costs), savings rates, interest rates, and taxation levels.

Liquid capital is theoretically the most mobile production factor. The cost of transporting liquid capital is almost zero, and it can be transmitted almost instantaneously in an electronically wired world. Fixed capital is much less mobile than liquid capital; for example, capital invested in buildings and equipment is obviously immobile and is the primary reason for industrial inertia. Any type of manufacturing that is profitable has an assured supply of liquid capital from revenues or borrowing (depending on its credit rating), and interest rates hardly vary within individual countries. Most types of manufacturing, however, initially require large amounts of fixed capital to establish the operation—or, periodically, to expand, retool, or replace outdated equipment or to branch out into new products. The cost of this capital, which is interest, must be paid from future revenues. Investment capital has a variety of sources: personal funds; family and friends; lending institutions, such as banks and savings and loan associations; and the sale of stocks and bonds. Most capital in advanced industrial countries is raised from the sale of stocks and bonds, although American firms rely on this approach more than do firms in Europe, where banks play a larger role in industrial financing. The total supply of investment capital is a function of total national wealth and the proportion of total income that is saved. Savings become the investment capital for future expansion.

Whether a particular type of manufacturing, or a given entrepreneur, can secure an adequate amount of capital depends on several factors. One factor is the supply of and demand for capital, which varies from place to place and from time to time. Of course, capital can always be obtained if users are willing to pay high enough interest rates.
Beyond supply-and-demand considerations, investor confidence is the prime determinant of whether capital can be obtained at an acceptable rate.

Capital is important as well because firms can substitute capital for labor in a process of capital intensification. The history of capitalism is largely one of capital intensification in different industries, particularly in agriculture, in which only a very small fragment of the labor force in industrialized countries now works. Capital intensification can increase productivity, but it may also displace workers. Only if the cost of goods drops sufficiently to increase real incomes and worker expenditures can it generate job growth in the long run.

Management

Management involves the nuts and bolts of corporate decision making, including allocation of the firm’s resources, raising investment capital, keeping abreast of the competition and government rules and policies, making investment decisions, hiring and firing workers, marketing and public relations, and similar types of functions. Corporate management reflects and shapes the organizational structure of a firm, including the pattern of ownership and how decisions are made. Firm management forms may range from sole proprietorships to partnerships and be either public or privately owned.

Within firms, management forms an important part of the corporate division of labor, that is, the headquarters as compared with branch plants. Corporate headquarters decide a firm’s overall competitive strategy, what markets and products to focus on, labor policies, engagement in mergers and acquisitions, and types of financing. Thus, these tend to be skilled, well-paying, white-collar jobs. Most are in large urbanized areas.

Technical skills are the skills necessary for the continued innovation of new products and processes. These skills are generally categorized as research and development (R&D). The R&D required for new products is typically a large and expensive process, involving long lead times between invention and production, a process that is often beyond the scope of small firms.

Barney Warf

See also Agglomeration Economies; Business Cycles and Geography; Business Geography; Commodity Chains; Economic Geography; Economies of Scale; Economies of Scope; Incubator Zones; Industrial Districts; Innovation, Geography of; Knowledge Spillovers; Labor, Geography of; Location Theory; Technological Change, Geography of; Telecommunications and Geography; Thünen Model; Transportation Geography; Zoning

Further Readings


Fair Trade and environmental certification refers to various labeling programs designed to bring accountability to globalized production systems that otherwise obscure a product’s sources and conditions of production. Amid food safety scares, environmental concerns, and ethical convictions, consumers and activist groups increasingly turn to certification systems to identify a product’s social and environmental qualities.

All certification systems involve standards, inspections, and a logo indicating that the product meets the standard. In the most influential certification projects, third-party auditors conduct inspections and grant the right to use certification logos. Many certification systems have also developed a network of independent organizations that govern inspections, license logos, and develop standards. Such certification networks constitute important new components of global neoliberal environmental policy.

There are a wide variety of environmental certification systems, including, for example, International Standards Organization (ISO) 14001, Blue Angel, Energy Star, the European Union Ecolabel, and the Marine Stewardship Council fisheries certification. Ecolabelling.org provides information
FAIR TRADE AND ENVIRONMENTAL CERTIFICATION

on nearly 300 eco-labels, including more than 70 food labels and 30-plus forest product labels.

Organic products have been third-party certified as produced, stored, processed, handled, and marketed in accordance with product-specific standards designed to maintain the health of soils, ecosystems, and people while avoiding inputs with adverse effects. From its roots as an alternative agricultural movement, organic farming has become increasingly codified and standardized, with recurring controversies about changing standards in ways that make it more convenient for large producers and retailers to offer organic products. In the United States, the sale of organic products increased from about $1 billion in 1990 to $17.7 billion in 2006. About 2.8% of food and beverage sales in the United States are organic. Global demand for organics reached $38.6 billion in 2006, double that in 2000. Forest certification is the process of evaluating forests or woodlands to determine if they are being managed according to an agreed set of standards. The most influential program is the Forest Stewardship Council (FSC), a multistakeholder institution that combines environmentalists, social activists, and private-sector actors involved in forest management and wood product retailing. As of September 2007, FSC certification reached 90,870,769 ha (hectares) and 886 forest management operations in 76 countries, equivalent to about 10% of the world’s managed forests. More than 200 million ha have been certified by competing industry- and government-led certification systems, but most environmental groups prefer FSC and question the rigor and legitimacy of the other forest certification systems.

With the goal of improving socioeconomic conditions for poor producers of handicrafts and food, Fair Trade promotes just and direct trading as an alternative to conventional markets. Certified Fair Trade producers must be organized democratically and comply with product-specific standards such as minimum quality and the elimination of certain chemicals. Certified Fair Trade traders must pay a price to producers that covers the regional cost of production, provide a premium that funds local social development projects, and comply with minimum quality and environmental standards. Many Fair Trade producers are also certified organic, especially in coffee.

After many years of direct marketing by faith-based organizations and well-known nongovernmental organizations, certification created new possibilities of selling Fair Trade–labeled products not just in specialty stores but also in conventional retail outlets. Social activist organizations such as Global Exchange and the United Students for Fair Trade pressured big retailers and demanded that on-campus vendors offer Fair Trade coffee and other products. The sales of Fair Trade–certified products grew 40% per year during the past 5 years. By 2007, 632 Fair Trade–certified producer organizations in 58 countries participated in a €2.3 billion worldwide market, directly benefiting an estimated 1.5 million workers and 6 million family members.

Some think that such certification instruments, and the social movements behind them, are transforming the way global corporations do business by making the implications of production and consumption choices clearer to consumers, retailers, and producers. They believe that certification allows activists to shame and also reward corporations for doing the right thing. Other observers suspect that certification’s ability to radically transform production processes is diminished when big distributors and retailers get involved. They fear that competing industry-led labels undermine the social and environmental goals of more stringent labels associated with multistakeholder groups or that industries might dominate certification organizations and use their influence to erode standards. Thus, they argue that the vigilance of activist social and environmental organizations is essential for certification projects to affect globalized networks of production and consumption significantly.

Dan Klooster

See also Agrofoods; Corporate Voluntary Environmental Initiatives and Self-Regulation; Environmental Certification; Neoliberal Environmental Policy; Organic Agriculture

Further Readings

Anyone attempting to define famine must be aware of the significant challenges involved. Definitions involve distinctions, but in the case of famine, such distinctions are especially fraught, not just because relief operations require “definitional clarity” but because the capacity to assign and apply meaning can be a powerful tool used to obscure or deny the violence done unto others. Indeed, some of the most destructive famines have been mystified, concealed, and disclaimed by making false and fallacious claims about the precise nature and cause of the disaster.

The definition and meaning of famine have changed with time. In the 18th century, demographer and economist Thomas Malthus argued that because the food supply was relatively inflexible, natural tendencies would increase the population at a much faster rate than the rate at which food could be produced. This propensity for the population to outstrip subsistence could only be avoided through preventive checks (i.e., late marriages, celibacy, abortion, and infanticide), by which human populations proactively limited their own progeny, or through what Malthus described as positive checks (war, famine, pestilence), which keep population numbers in proportion to the means of subsistence. Malthus’s “population principle,” as it became known, established an enduring association between food

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<td>93</td>
<td>288</td>
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<td>Global Total</td>
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<td>2,450</td>
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**Table 1** Number of people living on $1 or $2 per day, 1981–2001. The benchmark levels of $1 or $2 per day are commonly used measures of extreme poverty that point to populations most susceptible to famine.

Figure 1. World map of famine-prone regions. Countries in which famine is most common are those with impoverished populations, common malnutrition, and vulnerability to humanly induced or naturally created disasters such as war or drought.

Source: The U.N. World Food Programme.
availability and famine while implying that famines operated as a natural check on human improvidence. Moreover, because only the most advanced European societies were capable of voluntarily restricting population growth, famines would remain an important natural check, especially for subaltern populations lacking social maturity and moral training.

In his groundbreaking book Poverty and Famines: An Essay on Entitlement and Deprivation, published in 1981, the Indian economist Amartya Sen directly attacked Malthusian food supply arguments for failing to consider how available foods might be unequally apportioned. Whereas Malthus emphasized “food supply,” Sen focused on the questions of distribution and “demand” within a market economy. To understand starvation, he suggested, it is necessary to analyze the commodity bundles (including foods, goods, and services) that a person can legally command by using his or her available resources and personal capacities. For Sen, famines result from entitlement failures brought about because a person’s assets, capacities, or terms of exchange (within a structure of ownership) shift to such a degree that it is no longer possible for him or her to directly or indirectly obtain the means of subsistence. A dearth of food is thus only one of many possible causes of starvation. Indeed, viewed through Sen’s framework, famines can occur where there is no overall decline in food availability and even in cases where there is an increase in general output—so-called boom famines—as happened in the Great Bengal Famine of 1843.

Sen’s entitlement theory has been widely praised for separating famine from the question of food availability and for debunking the common myth that famines are natural catastrophes. For others, however, Sen’s approach remains entrenched within the modern epistemology of famine. Whereas Malthus viewed mass starvation as the failure to temper the “passion between the sexes,” Sen represents famines as a collapse of entitlements—a failure of another kind. For critics, this view tends to produce a technical or managerial approach to famine that isolates hunger from particular relations of power. This arguably leaves entitlements theory bereft of a concept of justice. Other critics point out that entitlement theory fails to take due cognizance of gender inequalities, especially entitlement changes among women, who are usually excluded from the historical record of famine. Gender relations are of course embedded within the social relations of society prior to famine and help explain why in times of crisis women can be abandoned, divorced, or sold into prostitution or slavery in the interests of male survival. Recent studies demonstrate that household entitlements are important and that women and children, especially female children, are particularly vulnerable to famine.

Sen is also criticized for focusing only on the “victims” of famine. Recent work has shown that famines—and other disasters—can serve particular political functions as benefits accrue to one section of the community while losses flow to the other. Indeed, it is by no means clear that there has ever been a famine where all sections of the population are equally affected. Famines usually leave behind a tense landscape of “winners” and “losers.”

It is also common to situate famine within broader discussions on health, welfare provision, and community access. Despite the customary focus on calories, deaths from starvation account for only a very small proportion of overall famine mortality rates. Most population losses result from a combination of poor diets (including the consumption of unwholesome or indigestible “famine foods”), the breakdown of sanitary conditions, and the spread of infectious diseases. The artificial congregation of populations—in feeding centers, refugee camps, and so on—can also create ideal pathogenic environments for the rapid spread of communicable diseases. On the other hand, traditional coping strategies (nomadic hunting, gathering, pastoral patterns, and migration from affected areas) can increase morbidity by exposing distant populations to famine-related diseases. Although crucial questions remain as to what exactly is epidemiologically distinctive about famine episodes, the simple assumption that famine represents a food crisis has been replaced by a more complex understanding of famine as a health crisis.

Finally, within the critical literature on famine, it is now generally accepted that famines do not necessarily begin with crop failures, droughts, or equivalent climatic hazards. On the contrary, their appearance generally occurs much earlier, when a population is made progressively vulnerable or
slowly brought to the point of collapse. Much of this insight is gained from studying colonial contexts, in which famines were often created through the erosion of traditional or customary food systems and the placement of imperial concerns over and above local subsistence needs. For this reason, some scholars prefer to shift their focus away from the “endgame” of famine—mass mortality—to the underlying or structural conditions that contribute to excess mortality. In their view famine is a process, not an event.

Our definition and understanding of famine has changed remarkably in 200 years. Now most social scientists accept that subsistence crises are unnatural social phenomena. Most social scientists also accept that famines are not discrete social events but reflect large and complex issues such as labor rights, gender inequalities, development strategies, state and corporate control of food, colonialism, market capitalism, and racist and institutional prejudices. These new mappings of famine connect seemingly disparate peoples, places, and events and reveal the complex ways in which privilege and suffering are mutually constituted. These lessons are crucial if we are to begin building more socially just and humane food economies.

David Nally

See also Food, Geography of; Hunger; Malthusianism; Natural Hazards and Risk Analysis; Neo-Malthusianism; Poverty

Further Readings


Faulting occurs when Earth’s crust ruptures as a consequence of accumulated stress; it is the most common cause of earthquakes. Along with folds, faults are the most obvious results of deformation within the crust and constitute the field of structural geology. While folds are the result of ductile (plastic) deformation, faults indicate brittle behavior and occur only in the relatively cold surficial layers of Earth, generally down to a depth of about 70 km (kilometers; 40 miles). Although faulting may cause vertical uplift, the stresses that lead to rupture are usually horizontal, related to movements along the boundaries that define the plates that make up Earth’s crust. Three types of movement predominate—extension, compression, and lateral shear—and lead to three major types of fault, commonly referred to as normal, reverse (thrust), and strike-slip faults. Because the type of fault is directly related to the orientation of stress in the crust, faults (even small or inactive ones) serve as sensitive indicators of those stresses that existed at the time the fault developed.

In defining faults, it is critical to observe the type of motion on the fault plane. Some faults are vertical, but the majority are inclined at some angle to the surface. The orientation of the fault plane (or any other planar surface in geology)
is defined by strike and dip, the strike being the geographic trend of the plane, given as a compass azimuth, and the dip, which is a direction and angular measure of the inclination from the horizontal, measured perpendicular to strike. In strike-slip faults the displacement is parallel to the strike, while in normal and reverse (dip-slip) faults the displacement is parallel to the dip. Faults that combine components of both strike and dip movement are said to show oblique slip. The side above the fault plane is referred to as the hanging wall, which dates from early mining terminology, while the side below is the footwall. A miner observing an inclined fault in a horizontal tunnel would stand with his feet on the footwall, with the hanging wall suspended over his head (Figure 1). The following definitions are based on the foregoing axioms.

**Faults and Joints**

A fault is a fracture that shows either vertical or horizontal displacement, possibly both. The three major types of fault depend on the orientation of stresses in the crust. A fracture without significant displacement is described as a joint.

**Dip-Slip Faults**

**Normal Fault**

When the crust is subject to extension, dip-slip faults develop in which the hanging wall block slides down the fault plane relative to the footwall block. The effect of normal faulting is therefore to lengthen the crust (Figure 2). The Basin and Range Province of Utah and Nevada is dissected by numerous normal faults indicating substantial extension, which continues to the present day. The basins (rift valleys) coincide with the down-dropped blocks (grabens), and the ranges are the up-thrown footwall blocks (horsts). Topographic rift valleys, formed by grabens delineated by normal faults, occur in East Africa and the Middle East, including the Red and Dead Sea rifts, and along spreading centers in the Mid-Atlantic Ridge (visible in Iceland), Mid-Indian Ridge, and East Pacific Rise. In all cases, the presence of active normal faulting signals that crustal extension is under way.

**Reverse Fault**

When the crust is subject to compression, dip-slip faults develop in which the hanging wall block slides up the fault plane relative to the footwall block. If the fault is at a relatively high angle to the surface (>45°), it is called a reverse fault. It is the reverse of a normal fault and leads to shortening of the crust (Figure 3A). In a high-angle reverse fault, the vertical throw is more pronounced than the horizontal displacement.
If a dip-slip fault developed due to compression shows an inclination less than about 45°, it is called a thrust fault. Again, the hanging wall block moves upward relative to the footwall block, indicating crustal shortening (Figure 3B). However, low-angle thrust faults are capable of producing extremely large horizontal displacements, measured in tens or even hundreds of kilometers. This is much greater than in high-angle reverse faults. Because folds are also a consequence of compression, thrust (and reverse) faults are common in folded mountain terrains. In the Alps, for example, the crust has been shortened and thickened by the stacking of masses of complexly folded rock (nappes) separated by major thrust faults. Similar associations of folds and thrust faults are characteristic of all continental mountain chains formed by compression.

**Faulting**

- **Strike-Slip Faults**
  - Many faults show little or no vertical (dip-slip) movement but show large horizontal displacements parallel to the strike (trend) of the fault. Such faults are referred to as strike-slip faults and are the result of lateral shearing (Figure 4). Depending on whether the sense of displacement is to the left or right as an observer looks across the fault, it is referred to as a left-lateral or right-lateral strike-slip fault. The San Andreas Fault, which separates the coast from the bulk of California, is the most famous of strike-slip faults. In 1906, accumulated stress was released in some 6 meters of right-lateral elastic rebound, which generated the San Francisco earthquake. The cumulative movement on the San Andreas and related strike-slip faults over about 20 million years amounts to at least 550 km or around 20° of latitude. Major earthquakes that occurred in Turkey (North Anatolian Fault) and China (Gobi-Tien Shan Fault) are also related to strike-slip motion.

- **Transform Faults**
  - The San Andreas Fault belongs to a special group of strike-slip faults, called transform faults, that connect and transform the motion between segments of a plate boundary with
slightly different vectors (especially segments of the mid-ocean ridge system). Most transform faults occur in oceanic crust and are necessary to accommodate plate motion and rotation on the surface of a sphere.

**Fault Scarps**

In some faults of relatively recent age, displacement may be evident at the surface as a *fault scarp* overlooking the down-thrown block. However, in time, erosion obliterates the surface evidence of motion, and changes in elevation across a fault are determined by the relative resistance of rocks exposed on either side. If the down-thrown side of a fault is capped by a resistant rock, it is possible to end up with a *fault line scarp* that overlooks the up-thrown block. To be certain of the type of motion, it is necessary to observe the displacement directly within the rock. This is especially evident when dip-slip faults intersect stratified sedimentary rocks (Figures 2 and 3).

*Timothy M. Chowns*

See also Basin and Range Topography; Earthquakes; Folding; Plate Tectonics

**Further Readings**


**FEAR, GEOGRAPHIES OF**

Geographers who study fear are interested in its social and spatial rather than purely psychological qualities. Fear is an emotional reaction to a perceived threat that acquires meaning from its context. It may have positive and negative effects on people and places. The interest of geographers in fear is long-standing, traditionally associated with studies of landscape and crime and most recently flourishing within the fields of emotional geographies and geopolitics. Fear inhabits, moves between, and shapes particular environments, altering the patterning of social relations. In turn, places may create or reinforce fear. Fear is implicated in restrictions on the use of space but also in reclaiming of space by individuals, groups, and organizations.

The earliest studies of fear in geography focused on subjective aspects of cultural and physical landscapes that interplay with human emotions. From the 1970s, attention was focused on the effects of crime on physical and emotional security in Western cities. The enduring mantra that fear presents as much, or more, of a problem than crime itself was born—arising partly from conservative governments’ shifting of responsibility for security to the individual and partly from the growing desire within the social sciences to measure and pin down social problems that seem unknowable. At the same time, the rapid attachment of the label *fearful* to certain people and places traced lines of sociopolitical hierarchy: Women, older people, and children were placed as quintessentially but irrationally fearful victims.

Feminist geographers joined critical realist criminologists in conducting intensive local research to contest such widespread constructions. They showed that fear and crime are concentrated among poorer neighborhoods and among groups with the least social and political capital. Fear is closely associated with systems of privilege that produce systemic violence (e.g., sexual, racist, and homophobic violence and child and elder abuse) that grounds and shapes wider social fears. Much of this violence and fear inhabit private spaces outside the traditional terrain of geographers’ focus of attention. Many social “others” who are the subject of cultural fear live with structural vulnerability and insecurity, for example, homeless people, people of color, recent migrants, and teenagers.

A closely related focus of geographical research has been the fortified city. As urban redevelopment has become increasingly corporate, fear has been used to justify exclusionary social and
physical planning. Policies seek to target and exclude “feared” groups whose presence intimidates or interferes with the economic imperatives of city spaces. Recent fears around terrorism have given new life to situational crime prevention through environmental management and surveillance, in opposition to the ideal of peopled, inclusive public spaces. Many such strategies have been criticized as anticommunitarian, easing the fears of some at a high cost to others.

Recently, these localized concerns have been joined by interest in “globalized fear,” relating to issues such as the war on/of terror, the threat of infectious diseases, and international population movement. Geographers have described the use of fear as a tool of governance, particularly the rallying of support for Western military intervention using fears about terrorism. Older anxieties about race are being recast in concerns over religious difference, with Muslims feeling especially insecure in the current geopolitical climate. The media are viewed as having a primary role in whipping up public fears: Long-standing notions about dirt, disease, and the “other” are remobilized as calls grow for a halt on immigration to the West.

The reconceptualization of fear as global, moving between and connecting faraway places in response to geopolitical events and processes, has tended to overlook previous work on the complex patterns of emotionality in local contexts. However, a growing body of geographical research has identified the sharp effects on security and fear among those groups that are themselves demonized, in rejoinder to the whiteness of “globalized fear.” Practices of intersubjectivity, everyday cosmopolitanism, and global social movements are among numerous strategies for resisting, remaking, and remobilizing fear; for security and survival; and to contest oppressive sociopolitical relations and policies.

The ways in which fear moves are currently presenting the most intriguing questions for geographers: whether fear follows people’s journeys through city and home spaces, shifts and fluctuates in tune with international flows of people and materials, or comes alive via the media or firsthand experience. Much research on the everyday and global assumes an uncomplicated, hierarchical movement of fear between different spatial scales or among different places. Recent reconceptualizations view fear as simultaneously global and everyday, collapsing any idea that emotions are scaled rigidly in experience or constitution. Affective geographies have explored the capacity of bodies to act as unconscious transmitters of feeling; their ability to affect people, places, and events may be deployed through oppressive practices or in forms of resistance. Analysis of the movement of fear in the wider field of emotional geographies evokes perceptions of place, psychotherapeutic landscapes, the structural and responsible aspects of well-being, and the conscientization (knowing, learning, and actioning) of fear.

Meanwhile, following the turn to positive well-being, work on geographies of hope has begun to explore its relation to fear and its place in social and spatial life. Yet stereotypes about Western fearfulness persist—about the motivations of “paranoid parents,” about mass fear during the war on terror, about what drives the overuse of automobiles. Geographers have pointed to the paucity of grounded research; to the dangers of ignoring the central place of social, economic, and political inequality in analysis; and to the need to study emotional landscapes outside Western urban contexts, where most research has focused to date.

Rachel Pain

See also Crime, Geography of; Emotions, Geography and; Terrorism, Geography of

Further Readings


FEBVRE, LUCIEN
(1878–1956)

Lucien Febvre, a historian by training, is a central figure in the history of geography as an advocate of the approach of the geographer Paul Vidal de la Blache, particularly after the latter's death in 1918. Born in Nancy in the Lorraine, Febvre received his doctorate in history at the Ecole Normale Superieur in Paris in 1911. He began teaching at the University of Dijon in 1912, but his career was soon interrupted by World War I. He resumed what would become an illustrious scholarly career at the University of Strasbourg in 1919, where he collaborated with fellow historian Marc Bloch. With Bloch, Febvre founded the soon to be prominent journal *Annales d'histoire et sociale* in 1929, beginning what is now known as the Annales School of history. Febvre was eventually elected to the prestigious College de France in Paris in 1933.

Vidal de la Blache was one of Febvre’s professors during his time at the Ecole Normale, and, taken with Vidal’s geographical approach, Febvre continued attending his lectures even after Vidal moved to the Sorbonne. From his earliest training as a historian, then, Febvre was greatly influenced by what was then the predominant regional approach taken by the early French school of geography. This continuing influence is clear in the Annales School’s approach to history, particularly its emphasis on what became known as the *longue durée* of historical evolution, so dominant in the work of perhaps its best-known member, Fernand Braudel.

Along with a corpus of historical works Febvre authored that are imbued with a strong appreciation of the human-environment relationship, his most important book concerning the study of geography is *La terre et l'évolution humaine*, published in 1922 and translated into English in 1925. This book is an extended defense of what Febvre considered to be Vidal’s geographical approach against growing criticism of it as merely descriptive. Such attacks came largely from those in the rather new discipline of sociology, influenced by Émile Durkheim, who considered their take on “social morphology” to be a more causal, scientific approach to the problem Vidalians merely described on the basis of their geographical studies of regional *genres de vie*.

Ironically, Febvre’s view came to be considered as the definitive statement of geography as a scientific discipline, and not just in France. The geography Febvre defends focuses exclusively on the human-natural environment relationship as it evolves over long periods of time in unique, regional settings. To Febvre, the regional monograph was the ultimate goal and singular achievement of geography. He completely missed Vidal’s emphasis on the causal processes—trade, transportation, and so on—that intersect to form such regions. Since Febvre’s work became so prominent a disciplinary reference, the works of the Annales School of history became more a legacy of Vidal’s own approach than what was actually followed in departments of geography in France and elsewhere.

Kevin Archer

See also *Annales School; Environmental Determinism; Vidal de la Blache, Paul*

Further Readings


FEMINIST ENVIRONMENTALISM

Feminist environmentalisms operate theoretically and politically at the nexus of the feminist and environmental social movements. What unites the multiple branches of feminist environmentalism today is a belief in the fundamental connection between the oppression/domination of women/minorities and the oppression/domination of nonhuman nature. In essence, feminist environmentalists argue that one cannot eliminate human domination of other humans (e.g.,
sexism) without working to dismantle all forms of domination, including human domination of the natural world. This entry outlines the major avenues for connecting feminist and environmental analyses.

In a Western context, the connections between the treatment of women and nonhuman nature have been around since the earliest days of the suffrage and abolitionist movements in England and the United States. Many of the women who took part in these movements were avid vegetarians and argued for better treatment of animals alongside better treatment of women and children, as well as an end to slavery. Women, often acting as “moral mothers,” were also central to turn-of-the-century campaigns to establish natural parks, to protest the decimation of bird populations for women’s hats, and to demand services such as clean water and clean food for their families. Rachel Carson’s 1962 book, *Silent Spring*, galvanized the modern environmental movement and laid the groundwork for many of the issues that feminist environmentalists focus on today.

In 1974, a French philosopher, Françoise d’Eaubonne, coined the term *ecofeminism* to give a label to what many feminists had been starting to feel about both the feminist and the environmental movements. Ecofeminists charged that feminists were not addressing environmental concerns and that women were experiencing a high level of sexism within the environmental movement. Furthermore, for many women, there was a sense that women were, in essence, more closely aligned with nature than were men. As women acted as women and as mothers in campaigns as diverse as exposing the toxic waste at Love Canal, protesting the costs of war with the Women’s Pentagon Action, and reshaping their spiritual connections by recovering ancient, goddess-worshipping cultures and practices, the first academic conferences were held addressing the connections between feminism and ecology, and a flurry of publications appeared challenging the essentialist tendencies of early ecofeminism. The choice of terms remains an issue for many working at this nexus; while some people see these terms as interchangeable, others disagree and choose the term that most suits how they view the relationship between women and nonhuman nature. Other charges against early ecofeminism focused on how it was developing as a largely white, middle-class, heterosexual movement that focused too much on “luxury” issues such as goddess worship and animal rights. Women of color and women from developing countries raised awareness about the need to focus on immediate survival needs (e.g., access to clean water) and environmental toxins affecting poor, minority communities. They stressed that while there might be significant connections between women, as a category, and the nonhuman world, there were acute differences between women in terms of their capacity to interact with nature and/or affect change.

Today, feminist environmentalisms continue to evolve in multiple directions and are increasingly active internationally. From a community activist standpoint, groups campaign on issues ranging from environmental toxins, green living, and ecosensitive spiritual practices to struggles over wilderness preservation, for local control over resource development, and against capitalist commodification of biodiversity the world over. For example, activists explore the issue of women and nonhuman animals by exposing the treatment of female livestock in industrial systems, the link between domestic violence and animal abuse, and the related objectification of women and nonhuman animals as bodies instead of as whole beings. Additionally, environmental feminists have continued to make tremendous statements about how different women experience or come to know or love nature through art—fiction, poetry, painting, sculpture, and film are all increasingly used formats for connecting gender to the environment aesthetically.
The emphasis varies theoretically as well. A tremendous amount of work has been done in uncovering the historical legacies of linguistic women-environment connections, through the use of terms such as *raping the land*, *virgin forests*, and *mother Earth*—language that reinforces the objectification of both women and the environment. Environmental historians have examined where, how, and when women have related to the environment and where and how those relationships have been constrained by patriarchal practices. Research from a political-economy and political-ecology perspective has highlighted how gender power differentials contribute in local situations (and via international aid) to control women’s access to resources and take resources away from women and even how the impacts of global climate change are going to disproportionately affect the world’s poor women. Other avenues in political economy focus on the consequences of militarization and wars for local women and environments. In summary, feminist environmentalism is a continually evolving perspective that seeks to dismantle mind-sets of domination that threaten the lives of not only all women but all people and the existence of non-human nature.

Julie Urbanik

See also Ecofeminism; Feminist Environmentalist Geographies; Feminist Political Ecology; Gender and Nature; Nature-Society Theory

Further Readings


Feminist environmental geographies seek to make explicit the spatial topographies of gendered relations with the natural world. Studies have focused on the ways in which women’s relationships with nature have been enabled or constrained and how male-dominated social-economic power structures have perpetuated environmental harm. This perspective draws on traditions within and outside geographic subdisciplines including political ecology, landscape studies, political economy, animal geographies, feminist geographies, and feminist environmentalisms. Some of the earliest work in this area began in the early 1980s with a focus on landscape studies, but in the early 1990s, a call to focus specifically on the connections between women, nature, and geographies was made by Cathy Nesmith and Sarah Radcliffe. They outlined three major strands of research: (1) nature, culture, and gender; (2) gendered relations of global development and environments; and (3) gendered landscapes and identities. The trajectory of this perspective has generally adhered to these broad categories.

Nature, Culture, and Gender

Feminist environmental geographers, like feminist environmentalists, see a connection between the treatment of women and the treatment of the natural world by male-dominated systems. Feminist environmental geographies, however, differ from the strands of ecofeminist theory that argue that women are essentially, or inherently, closer to nature than are men. Instead, within geography this relationship is seen as one that is mediated by a variety of social and economic factors; so while it is important to uncover the geography of women’s experiences with the natural world, it is also crucial to put those experiences in larger, structural contexts. Perhaps no one has been more influential within geography in making explicit the link between nature, culture, and gender than Joni Seager, who was one of the first geographers to articulate a comprehensive feminist and environmental analysis. Her research revealed the
structural contexts of environmental harm by highlighting how ordinary people are not degrading the environment and that it is specifically a patriarchal capitalist system that continues to view nature (and women) as expendable commodities. Research in this area has exposed practices such as global militarization, international resource extraction in mining and timber, and food production through international patriarchal capitalist systems—all of which endanger the health of humans and the planet.

In addition to a more straightforward political-economic analysis of gendered environmental issues, another active strand of feminist environmental geography focuses on the nature, culture, and gender intersection specifically through the context of human-animal relationships. In the growing subfield of animal geographies, feminist geographers were the first to call for the opening of the black box of nature to reveal the myriad sentient beings on the planet and humans’ relationships to them, which have long been overlooked within geography. The argument is twofold. First, nonhumans have been “othered” by a human-centered society (and geography), that is, seen as objects and/or background to human actions instead of as agents or actors in their own right, and this has resulted in horrific treatment of food, companions, and wild animals. Second, this othering is heavily gendered. Jody Emel’s research on gender and wolf eradication is an influential example of this intersection. She highlights how the project of wolf eradication (and return) in the United States was directly correlated to the white male project of eradicating Native Americans and laying claim to dominating the land and removing competitors (both human and nonhuman). The literal and attitudinal violence shown toward wolves dramatically reversed itself with the rise of a men’s environmental perspective in the 20th century that suddenly saw wolves as emblematic of the “wild” man—something to be embraced instead of exterminated.

Feminist environmental geographers have gone on to point out how using animals as symbolic foils for humans has repercussions for the treatment not only of nonhumans but also of human groups (such as women or minorities) that get placed in animal-associated categories. In addition, several studies have continued to point out the ways in which experiences of nonhuman others is gender dependent—whether in relation to categorizing animals or in trying to find alternative, non-hierarchical, and nondominating ways to bring them more visibly as actors into our social, political, and economic systems.

A second major strand of research for feminist environmental geographers focuses on issues pertaining to gendered relations of development and environmental decision making. Political ecology examines the causes and consequences of unequal access to, and control over, natural resources, largely in the developing world. Feminist political ecology has emerged as a prominent strand in this field by arguing that gender is a critical variable in exposing the politics of resource use and allocation. In the first anthology of feminist political ecology research, the editors highlighted how a gender analysis helps reveal gendered knowledge about the environment and gendered systems of environmental rights and how gendered environmental activism at the grassroots level is challenging women’s historic exclusion from participatory resource use decisions. A plethora of studies have clearly demonstrated that empowering women around the world with respect to resource use is a key part of global environmental sustainability and social justice.

The issue of gendered environmental decision making and resource access is not limited, however, to developing countries. Paralleling feminist political ecology’s focus on the global South has been research examining gendered relations in industrialized countries, in particular the United States and Canada. One strand of work has explored gender issues within the environmental justice movement, which strives to expose how people of color and people of low income bear, disproportionately, the costs of environmental pollution and industrial development. Research demonstrates that even in a movement such as this, women do the majority of grassroots activism but hold fewer positions of power and yet in many cases have been able to affect change by successfully bridging traditional gendered and social divides between private and public spaces. Another
A strand of studies has examined gendered power relations in participatory decisions around resource use in forestry, mining, and fishing. Leaving women out of decision-making processes not only works to their disadvantage economically but also reinforces problematic power relations between men and women that inhibit widespread implementation of sustainable-use practices. Furthermore, researchers argue that it is not just the “adding in” of women that is necessary but also a fundamental reconceptualization of how environmental actors are defined and incorporated into decision-making bodies that will remedy women’s exclusion.

**Gendered Landscapes and Identities**

Landscape studies are concerned with how humans experience the built and natural world around them, how they represent it, and how lives are affected by different landscapes. Within geography, the field began to blossom in the 1970s and 1980s as geographers began incorporating insights from literary criticism and art theory to focus on questions of power, colonialism, and different types of landscapes (i.e., rural, wild, urban). Feminist geographers were quick to realize that not only has history been dominated by men’s definition of landscape (and their manipulation of it) but even in geography men have dominated cartography and interpretation. Building on environmental feminist theory about how women and nature have been historically conflated and seen as less than (white) men, feminist environmental geographers brought those insights into landscape studies. One of the most influential pieces along this line of thought comes from Gillian Rose, who argues that the male gaze, or visual masculinity, has not only been the dominant form of “seeing” landscapes but it also hides power relations, conflates nature with women’s bodies (e.g., nature’s bosom, virgin forest), and contributes to notions of human separation from the natural world.

While this line of research is key to revealing the gendered power relations of landscapes, a concern has been voiced by some that this does not go far enough in demonstrating where and how women have had agency toward the landscape. Therefore, a parallel line of studies has examined cases such as how women farmers experience their farms as landscapes; how suffragettes in the United States “rewrote” the masculine western frontier by demanding a more prominent role for Sacagawea, the guide for Lewis and Clark; how women experienced western expansion in the United States; and how males and landscapes can be conflated for women. The aim of all these case studies is to highlight not only where and how women have created their own agency with respect to living in and experiencing the landscape but, more important, that there is no “static” gendered landscape experience. Instead, landscape studies reveal the inherent contextuality of where, how, and by whom landscapes are lived and conceptualized.

In summary, feminist environmental geographies encompass a wide variety of perspectives and avenues of research. They are united, however, in their urgency to reveal the harmful power relations that are affecting both women’s empowerment and survival around the globe and the environmental health and sustainability of the planet itself.

*Julie Urbanik*

*See also* Animal Geographies; Ecofeminism; Feminist Environmentalism; Feminist Political Ecology; Gender and Nature

**Further Readings**


Feminism is a political project that asserts the social and political equality of the genders, particularly with regard to the underprivileged status of women in comparison with men. Thus, contrary to much popular opinion, feminism is not concerned simply with women but with gender relations, that is, the webs of masculinity and femininity that shape power, the allocation of resources, and the rhythms of everyday life. Although feminists operate from within a wide spectrum of perspectives, they concur that social reality is gendered, that is, that gender cuts across, intersects, shapes, and is in turn shaped by other lines of social organization such as class, age, ethnicity, sexuality, and geographic location. In denaturalizing gender—in exposing its social origins and power relations—they injected the first non-class-based form of social determination. In this view, to ignore gender and the profound difference it makes is to assume that male lives are the “norm,” a common, if implicit, view embedded in a wide variety of social theories and models. Indeed, for much of the history of geography, women were notable primarily through their conspicuous absence as subjects or producers of geographic knowledge.

At the core of feminist theories lies the notion that gender does not simply consist of the vast differences between males and females in terms of outlook, behavior, speech, movement, and opportunities but that gender differences are all too often constructed around male advantage and female disadvantage. Almost everywhere, today and throughout history, women live in a subordinate social position to men. More often than not, they work more, earn less, enjoy less social autonomy and fewer political rights, and culturally often garner less respect. A core focus of criticism in feminist scholarship is patriarchy, that is, social systems that create male advantage and female disadvantage. Patriarchal social relations penetrate the spheres of both production and reproduction and generally lead to representations of males as strong, rational, and active and females as weak, irrational, and passive. Feminism as a political project seeks not to end gender differences per se (the simplistic stereotype advanced by many conservative antifeminists) but to end the power relations that accompany gender. In this respect, being a feminist is not the same as being feminine; moreover, while many women are not feminists, and subscribe to traditional, sexist gender roles, some men are feminists.

Feminist Politics

Feminism as a political movement reflects and in turn contributed to numerous changes historically in the status of women. In the United States, its origins may be traced to 19th-century suffragists, particularly to the 1848 Seneca Falls conference, organized by Elizabeth Cady Stanton and Susan B. Anthony, which, among other things, advocated the right of women to vote, own property, and enjoy equal child custody rights in the event of a divorce. A second wave of feminism shook the Western world starting in the 1960s in the wake of the civil rights movement, personified in scholars such as Simone de Beauvoir and Betty Friedan. This second wave led to the growth in the number and power of women’s organizations concerned with a wide array of issues related to women’s opportunities, health, and safety, such as legalized birth control and abortion (e.g., the Roe v. Wade decision of 1973) and challenges to gender-discriminatory laws. The third wave of feminist thought arose in the 1990s, as exemplified in the works of feminists such as Audrey Lorde and bell hooks. It emphasized the diversity of women, particularly class and ethnic differences, as well as differences in sexual orientation.

To understand feminism, it is essential to appreciate its diversity: There is not one, monolithic feminism but many feminisms. Liberal feminists, for example, have long argued that women have intrinsic value and rights as people (“Feminism is the radical idea that women are human beings”). Marxist feminists maintained that the status of women is inseparable from class relations and hence from relations of property and production; in this view, gender inequality is essentially the product of capitalism. Radical feminists suggest that women’s experiences are fundamentally different from those of men by virtue of their being marginalized, and they stress “women’s ways of knowing,” a notion that critics hold essentializes women. Feminist psychologists such as Nancy Chodorow tend to focus on
gender differences in sex roles and socialization. Postmodern feminists unpack the category “woman” to reveal its enormous diversity. Post-colonial feminists seek to map out the varieties of patriarchy around the world and how Western-ized forms of thought naturalized them, such as in the contrast between “rational,” male Europe and an ostensibly passive, feminine developing world that it penetrated and conquered.

The relations between capitalism and patriarchy, in short, are contingent, not necessary.

Feminist geographers have explored the intersection of gender and space in many ways. For example, some have focused on the body, “the most intimate of geographies,” that “closest in” to the self as it plays out over time and space. For most women, the landscapes of fear, particularly fear of violent sexual assault, loom large; sadly, half the human race lives in terror of the other half.

The household as a locus of patriarchal relations and social reproduction has received wide scrutiny from feminists. Indeed, feminism opened up the family as an object of geographic scrutiny. The male-dominated family has been positioned at the core of innumerable studies of domestic violence, gender socialization, and household divisions of labor. Feminist economists note that while the bulk of unpaid housework and child care is done by women, it does not enter into national economic accounts such as gross national product or gross domestic product, which privilege male forms of commodified labor. Feminist geographers note that while women’s spaces are often discursively coded as private and interior, male spaces tend to be equated with the public realm outside the home. Within the home, male chores are often located outside, while women’s work is generally located inside. For some feminists, the entire dichotomy between production and reproduction, the “economic” and the “social,” is itself an inherently patriarchal idea.

The growth of services of many types fostered rising rates of female labor force participation, including growing legions of women in professional occupations, although the common complaint of a “glass ceiling” persists. As women entered the workplace, their changing roles reverberated to change gender relations at home and raised issues for two-income families concerning child care. Feminists challenged, for example, the common assumption in urban models of household commuting that the location of male jobs and the length of male commutes dominated the household location decision process. Moreover, the emphasis on male breadwinners and “stay-at-home moms” ignores the profound differences among women: Latinas and African American women, for example, have long worked outside
the home in greater proportions than have white women. Others have focused extensively on gender differences in commuting, which can be substantial given that a disproportionate share of women work in part-time “pink-collar” positions and assume the bulk of responsibility for child care. Thus, feminist urban geographers have sought to ascertain whether women’s generally shorter commuting times reflect their employment status or their domestic responsibilities.

Other feminist geographers pointed to the feminization of poverty, that is, the disproportionate representation of female-headed households among those living below the poverty level. Feminist political geographers examined gender differences in voting patterns, which vary widely over space and time, particularly the “gender gap,” which leads women to vote more frequently for socially progressive candidates and perspectives. Feminist economic geographers such as Linda McDowell explored the role of gender in industries such as finance, noting how banking circles both drew on masculine pools of labor and in turn produced them in particular locales. Because women are charged with the bulk of household consumption, feminist studies of their shopping behavior hold great import for geographers, economists, and sociologists alike. Yet others point to how public policies ranging from neoliberalism to welfare reform affect women in ways that are often quite different from their impacts on men.

Many feminist geographers focus on women in the developing world, including the numerous disadvantages under which they labor compared with men. The daily rhythms of work for women in Africa, Latin America, and Asia revolve around sets of tasks and nodes of social interaction different from those for men. Many women, for example, are responsible for fetching water and gathering firewood. The propensity of women to migrate tends to be lower than that of men, and they tend to be receivers of remittances rather than senders. Many women suffer extreme difficulties in gaining access to education and other public services. Famines strike women differently than the way they strike men, who may eat while their wives and children go hungry. As global capitalism has spun off a variety of low-wage assembly jobs to the global periphery, it has drawn millions of women into commodified labor markets.

Feminist Methodological and Epistemological Contributions to Geography

Feminism not only profoundly altered what geographers study—that is, raising gender to the center of geographical analysis—it also changed how they go about understanding men, women, and space. In this sense, feminism elevated gender from the ontological (the “real”) to the epistemological (the “philosophical”). Part of this change involved a novel set of methodologies; feminists were at the forefront in challenging positivist (and arguably masculinist) biases toward quantitative methods and their associated assumptions of objectivity, and in turn, they legitimized the use of methods to explore the subjective worlds of lived experience. Indeed, feminism helped pioneer and popularize the use of a variety of qualitative research methods (e.g., participant observation, standpoint theory, and grounded theory). In this respect, feminists helped clarify the implications of the power relations that exist between researchers and their subjects and helped foster techniques that emphasized the construction of a dialogue in which empathetic understanding loomed large. Feminist scholarship helped force researchers to clarify their own subject positions, limit the scope of their claims, and acknowledge that knowledge is always context bound, that is, that every view is a view from somewhere.

Equally important were the far-reaching implications of feminist epistemology. Some feminist philosophers of science, such as Sandra Harding and Donna Haraway, had long raised devastating critiques of masculinist science as an act of conquest, one that sought to dominate nature rather than understand it, and as a perpetuation of a “phallocentric” view that equated rationality with masculinity. Among geographers, Gillian Rose pioneered the understanding of geographical knowledge as gendered, particularly its traditional assumption of the neutral Cartesian subject, that is, the active male observer who “knows” and hence controls the passive landscapes of study. In an understanding that became widely popular, to assume that one knows is to assert authority, that is, to code others as simply objects of study whose lives are transparent to the all-powerful, all-knowing male knower. In contrast, feminist methodologies have encouraged geographers to be more patient, more empathetic in their explorations of people’s daily geographies.
Feminist methodology connotes a way of analyzing and theorizing research methods, principles, and knowledge production from a feminist perspective. In particular, it seeks to render visible the power relations of everyday life and of academic scholarship. Reflexivity and situated knowledge undergird this methodology. Scholars in human geography subdisciplines tend to deploy this methodology and often relate qualitative and quantitative methods. Research strategies driven by a feminist methodology usually hold political and social change as necessary motivations for and outcomes of academic study. By design, this research is frequently multiscalar and attuned to contextual variability.

Much like poststructuralism and postmodernism, the designation of a specifically feminist methodology emerged during the cultural turn. Geographers began to engage more closely with feminist views of knowledge production in the 1990s, and feminist methodology has continued to gain traction and application within the field since then. Notable contributions of feminist methodology to geography include making explicit unspoken or hidden perspectives, legitimizing research into such areas, and examining processes at multiple and fine scales.

Initially, feminist research about women and the category of Woman pioneered the use and development of a feminist methodology. Over time, feminist research broadened its purview and began to unpack meanings and representations of femininity and masculinity. Shifts within the intellectual landscape subsequently led feminists to investigate gender relations and gendered spaces and places. Feminist methodology commanded an important position in many of these research endeavors. In contemporary scholarship, feminist methodology considers myriad power relations, including but not limited to gender. A feminist methodology does not present power as static and passive. Instead, it highlights the relationality of power at all research stages. This emphasis works to disrupt essentialized perceptions of people, places, identities, or experiences. Rather than reproducing singular
or reified representations, a feminist methodology helps scholars foreground micronarratives and dynamic social processes. The joining of feminist methodology and feminist empirical topics throughout the years has led to a greater focus on underexamined geographic scales, especially the household and the body.

Studies informed by feminist methodology draw on a range of research techniques, such as interviewing, focus groups, archival work, participant observation, statistical analysis, and geographic information systems and science. Although feminist methodology has been linked most closely with qualitative methods, current research projects incorporate quantitative and mixed-method approaches as well. What ties these disparate methods together under the heading of feminist methodology is a shared sensibility about how research unfolds and what needs to be accounted for throughout the research process. In short, feminist methodology foregrounds power relations, compels scholars to consider their own roles in all phases of data collection and analysis, and accents the partial and situated nature of knowledge production.

Awareness of the researcher’s influential presence in and relationship to knowledge production constitutes reflexivity. Feminist methodology uses reflexivity to make visible the power relations weaving through a study and everyday life. Reflexively considering the gendered, classed, and raced aspects of research, for example, prompts different questions from alleging the perspective of the separate, and purportedly all-knowing, observer. Reflexivity as a process helps illustrate how both researcher and research subjects jointly produce knowledge within and through numerous and unequal power relations.

An explicit recognition that all knowledge comes from someone and somewhere—that it is situated—and that no research project is fully exhaustive—everything is partial—underpins feminist methodology. Rather than discussing situated knowledge as an excuse for shortcomings or as a limitation in understanding, feminist methodology builds on these insights and mobilizes them to fracture assumptions about academic objectivity. This research strategy and style of analysis are political statements because they explicitly challenge presumed separations between “object” and “knower” and question suppositions about who produces and who consumes what kinds of knowledge.

Teasing out various power relations and norms of authority—evident, for example, between the researcher and the researched and between different sectors of the academy—is central to feminist methodology. Power is understood as contingent, multidimensional, and relational. For example, a study that examines perceptions of race within urban spaces and involves a white woman interviewing women of color might well focus on the structural differences of gendered racialization. At the same time, it will also engage other facets of identity (such as age, socioeconomic class, ability, sexual orientation, and educational background) and spatiality (such as where the interview occurred, what places are described in the conversation, and what race means at different scales). In other words, the co-constitution and relationality of power dynamics within the interview context itself as well as within each phase of the research would require careful analysis when viewed through the lens of feminist methodology.

In recent years, participatory action research (PAR), intersectionality, and transversalism have emerged as new relational and politicized possibilities for feminist research and have informed feminist methodology as a result. While PAR, intersectionality, and transversalism are disparate in theoretical specificity, these approaches all address power relations, the role of the researcher(s), and the situatedness of knowledge production. Thus, they offer new avenues for exploring the central tenets of feminist methodology. The robust debates surrounding these theoretical interventions both within and beyond geography suggest that feminist methodology maintains a growing and vibrant place within the academy.

Serin D. Houston

See also Cultural Turn; Difference, Geographies of; Discourse and Geography; Feminist Geographies; Gender and Geography; Identity, Geography and; Qualitative Methods
FEMINIST POLITICAL ECOLOGY

Feminist political ecology is an emerging interdisciplinary field of study that has grown out of gaps and convergences between political ecology, women’s studies, environmental justice, and feminist development studies. It first appeared as a series of dispersed, parallel efforts to address the overlap between theory and practice across the academy and a diversity of social movements, spanning feminist, environmental, and development alternatives concerns. The explicit introduction of the term feminist political ecology in the 1990s was a conscious effort to join the ecological feminism and feminist cultural studies of science in Europe and North America with critical approaches to gender and development and sustainable development and to bring a feminist sensibility and analysis to the new and expanding field of political ecology.

As with political ecology in general, feminist political ecology coalesced in part as a broad critique of early sustainable development efforts. It specifically targeted three trends in the 1980s and 1990s. One was the continuation and proliferation of development programs that threatened forests, water, local food production, and rural livelihood systems as well as women’s environmental knowledge, authority, and traditional rights to land and resources. The second trend was the rapid growth of development projects with a shared focus on gender and sustainable development that often resulted in further exploitation of women’s labor and “natural resources” and in deepening conditions of poverty and inequality in rural areas. The third trend was the separate treatment of urban and rural environmental and social justice concerns and the widening gulf between parallel pursuits of political ecology (academic, rural, with a focus on “developing areas”) and environmental justice (movement driven, North American in origin, urban and/or industrial cases).

As in political ecology, some of the contributors now recognized as foundational did not originally identify themselves as feminist political ecologists. This group includes Judith Carney, Marianne Schmink, Jan Momsen, Cindy Katz, Carolyn Merchant, Val Plumwood, Donna Haraway, Joni Seager, and Betsy Hartmann. Others explicitly coined and embraced the term and invoked a set of shared principles and convergent concerns, as well as distinct theoretical positions and approaches to addressing problems. Several other scholars (including Dianne Rocheleau, Barbara Thomas-Sluyter, Esther Wangari, Richard Schroeder, Wendy Harcourt, Arturo Escobar, Lisa Gezon, Susan Paulson, Juanita Sundberg, Alice Hovorka, and Yvonne Underhill) have used the term feminist political ecology and framed articles and books and edited volumes around this conceptual framework, with changes constantly introduced along the way.

Feminist political ecology was consciously launched, in the edited volume by the same title, as a platform for discussions across the lines of feminist geography, women’s studies, feminist anthropology, gender and development, critical development studies, political ecology, and environmental justice. Academics sought to bring together authors and related social movements already addressing parts of this convergence. They
identified five existing clusters of feminist scholarship and activism defined loosely as ecofeminist, feminist environmentalist, socialist feminist, feminist poststructuralist, and environmentalist. Three major themes were invoked: (1) gendered knowledge and sciences of survival; (2) gendered rights and responsibilities with respect to land, resources, and environmental decision making; and (3) gendered social movements and organizations.

The early works identified with this field were primarily focused on gendered distribution of resources, unequal terms of access to resources, and unequal vulnerability to the depredations of development (what Vandana Shiva calls “maldevelopment”) in rural forest or agrarian settings. The literature has increasingly recognized and analyzed the strengths of women’s organizations and social movements and the contributions of women within broader environmental and social justice movements. Feminist political ecology is also increasingly concerned with multiple kinds of gendered power relations, both positive and negative, entangled with race, class, culture, ethnicity, and other axes of power that suffuse both social and ecological relations. Discourse analysis of gendered institutions in sustainable development has led to in-depth analysis of seemingly simple categories such as nature, women, men, land resources, and ecological systems.

Feminist political ecology entered early into the application of political ecology in urban areas and has begun to extend the insights of feminist urban geography studies on place and space into rural and international contexts where political ecology analysis has been most often applied. Feminist political ecology pioneered the inclusion of urban and industrial case studies in political ecology, although it has not always been recognized and acknowledged. Political ecology has recently expanded to include more work on urban and industrial settings. There is also a strong feminist poststructural and postcolonial element in much of the current feminist political ecology literature, as presaged in the early publications defining the field. Feminist political ecology has acknowledged the role of culture and place in shaping gendered environmental work, knowledge, experience, and perspectives, while also recognizing the reciprocal role of gendered environmental experience in creating distinct places and cultures.

The work of feminist geography has contributed much to theories of place, space, culture, identity, and dispersed power in feminist political ecology, while political ecology has contributed an understanding of the social relations of power at the nexus of culture, nature, and production. Feminist political ecology studies on gendered systems of land and resource tenure have also illustrated the many types of resources, and the diverse rights, uses, and users that may be entangled in the complex landscapes of development projects and programs. The complexity of gendered tenure, livelihoods, identity, and practice has forced open a window that allows us to see beyond simple definitions and maps of property, place, production, and conservation. As noted by Arturo Escobar, the increasing use of poststructural theory in political ecology has been driven in part by feminist and postcolonial insights.

Some of the most illuminating recent works in feminist political ecology have been those that combine culture, race, and gender, such as Juanita Sundberg’s account of indigenous identities emerging, from within and without, in the Guatemalan parks and reserves in Mayan areas south of the Mexico-Guatemala border. Going beyond many critical political ecology studies on parks and conservation policy, Sundberg’s feminist political ecology analysis highlights the complex struggles and manipulation of identity by multiple actors. She uses a feminist poststructural approach to explain how gendered and racialized landscape formations are created through daily practice, as well as by policy, in nature conservation organizations. Wendy Harcourt likewise brings new feminist scholarship on the body to bring bodies back into our understanding of gender, race, nature, and culture. The International Working Group on Women and the Politics of Place, convened by Harcourt and Escobar, defined a series of gendered environments, ranging from the body to the home, the community, and surrounding ecosystems. Because of the emphasis in addressing difference, and questioning categories, feminist political ecology has been able to complicate dualistic visions of the world, especially those relevant to the politics of conservation and development across scales, as well as emerging and complex livelihood systems and landscapes.
Finally, feminist political ecology has been adopted as a working framework for policy and advocacy by an international coalition of women from developing countries, DAWN (Development Alternatives for Women of a New Era), as well as the women’s nongovernmental organization caucus that met at the World Summit on Sustainable Development, convened by the United Nations in Johannesburg, South Africa, in 2002.

Dianne E. Rocheleau

See also Chipko Movement; Ecofeminism; Feminist Environmentalism; Feminist Geographies; Gender and Nature; Political Ecology; Sustainable Development

FERTILITY RATE

The term fertility, as used in the social sciences, refers to the actual births of children, and the fertility rate attempts to gauge the number of children being born into a population. The simplest of these rates is the crude birth rate (CBR), which is the number of live births in a year divided by the total midyear population. It is usually multiplied by 1,000 to reduce the number of decimals. The CBR is “crude” because it does not take into account which groups of people in the population were actually likely to have births and ignores the age structure of the population, which greatly affects how many live births can be expected in a given year. Thus, the CBR (which is sometimes called simply “the birth rate”) can mask significant differences in actual reproductive behavior between two populations and, on the other hand, can imply differences that do not really exist.

The general fertility rate (GFR) uses information about the age and sex structure of a population to be more specific about who actually was at risk of having the births recorded in a given year. The GFR (which is sometimes simply called “the fertility rate”) is the total number of births in a year divided by the number of women of childbearing age (typically 15 through 44 yrs. [years]).

Further Readings


One of the more precise ways of measuring fertility is the age-specific fertility rate (ASFR). This requires a rather complete set of data: births according to the age of the mother and a distribution of the total population by age and sex. The ASFR is the number of births occurring in a year to women within a given age group per 1,000 women of that age (usually given in 5-yr age groups). ASFRs require that comparisons of fertility be done on an age-by-age basis, but demographers have also devised a method for combining ASFRs into a single fertility index covering all ages. This is called the total fertility rate (TFR), and it is the sum of the ASFRs over all ages. Note that if the ASFRs are calculated for 5-yr age groups, then the sum of ASFRs must be multiplied by 5, whereas if data by single year of age are available, that adjustment is not required. The TFR can be readily compared from one population to another because it takes into account the differences in age structure and its interpretation is simple and straightforward. The TFR is an estimate of the average number of children born to each woman in her lifetime, assuming that current birth rates remain constant and none of the women dies before reaching the end of the childbearing years. A rough estimate of the TFR (measured per 1,000 women) can be obtained by multiplying the GFR by 30 or by multiplying the CBR by 4.5 and then again by 30. Although there are several other indices that are used as fertility rates, the CBR, GFR, and TFR are the most common.

John R. Weeks

See also Demographic Transition; Mortality Rate; Population Geography

Further Readings


Fieldwork has long been recognized as an important activity for geographers, in both teaching and research. Carl Sauer, one of the most influential geographers of the 20th century, stated that the principal training of a geographer should come from doing fieldwork. One of the most rewarding and enjoyable aspects of being a geographer is spending time understanding the world through direct experience, gathering data about the world, and leading field experiences as a method of geographical education. This entry briefly reviews the history of fieldwork, examines its characteristics, and considers its role in geography today.

However, despite the recognized importance of fieldwork, many have lamented its decline, particularly in the field of human geography. Wilbur Zelinsky, a respected human geographer, finds the basic explanation to be the ever-greater availability and sophistication of substitute means for gathering physical and social data. He criticizes those who avoid leaving the comfort of the library and believes that the importance of fieldwork will return once again as academic fashion swings the other way. The decline of fieldwork has been attributed to a number of factors, including stringent educational budgets, safety and insurance concerns, pressure for research output in universities, and a growing emphasis on GIS analysis. A further result of this decline in field education is the dwindling opportunity to acquire formal training in field instruction. This lack of formal training is particularly acute at the university level, although one bright spot is the increasing use of computer technologies to provide “virtual fieldtrips.”

Fieldwork in human geography is often linked to the classic work of the Chicago School, which refers to the body of research that emerged during the 1920s and 1930s in urban sociology and geography that combined theory and fieldwork. This early work aimed at understanding the daily world experienced by different subpopulations in Chicago through field research, including, for example, Louis Wirth’s vivid description of life in the ghetto. The fusion of studying spatial form
and more subjective styles of living created the Chicago School’s distinctive interactionist sociology, which viewed society not as a stable or fixed structure but one constructed on interaction.

Perhaps one of the best examples of a geography of the human experience is David Ley’s description of the inner city as a frontier outpost. Using a wide range of research techniques, including fieldwork, Ley explored the variety of images of an African American inner-city neighborhood in Philadelphia, using those from outside and from within. He viewed the neighborhood as a frontier outpost, having an external environment of hostility and uncertainty and an internal environment that focused on connectivity and cultural separation as a way to meet the challenges imposed by the external environment.

Graham Rowles used fieldwork to explore the geographical experience of the elderly. He went beyond observation in the field to becoming involved. Rather than remaining as the traditional dispassionate observer, he became involved in the experience. Rowles’s research techniques involved sharing conversations with older people in their homes, at community meetings, and in other everyday life experiences. The outcome was a collection of five vignettes describing the geographical experiences, combined with a developed theoretical perspective. Rowles discusses five elements of conducting experiential fieldwork. The first element is involvement with participants: Unlike more traditional research, in which no attempt was made to minimize the role of the researcher, emphasis was placed on mutual understanding through dialogue rather than simply observation. The second element is the lengthy time investment required to allow individuals to express themselves in their own way. The third element is the limited number of participants. Because of the small sample size, breadth of generalization is sacrificed for depth of insight. The fourth element is the emphasis on induction as opposed to deduction. The last element is the presentation of the text, which Rowles argued is best presented in a format emphasizing a subtle sensitivity to expression.

Despite the fact that leading schools of geography currently require little training in field methods, fieldwork in human geography has continued and is today more than personal observation and recording. Today fieldwork involves not just understanding the landscape and includes, for example, interviewing children to uncover their views of space and much of the work that has been done detailing the views of women and their roles within the geographical experience. This wide breadth of work has been undertaken more critically, especially in understanding power relationships between the observer and the observed. Today there is also a necessary and worthwhile discussion concerning reliability issues.

Jennifer Hyndman views fieldwork as an exercise in communication, trust, and timing. Through the learning of language, extended stays, and a slow building of trust and rapport, researchers become part of the field. Despite the intellectual, sociocultural, and economic baggage that field researchers take along, they never return “home” quite the same. The researcher using fieldwork, like the travel writer of the past, is changed by exposure to new places and insights, and he or she returns to a changed place.

### Evaluating Fieldwork

The challenges involved in guarding against threats to reliability continue to be discussed in qualitative research and among those conducting fieldwork. Most agree that the key to validity is clarity. Baxter and Eyles have created a set of criteria for evaluating qualitative research that often requires fieldwork and interviewing: credibility, transferability, dependability, and confirmability. They claim that the most important principle for guiding qualitative and field research is the notion of credibility. This credibility is best measured by the degree to which those who are described would recognize their experience and those outside can understand it. Transferability refers to the degree to which findings can fit into contexts beyond the study. The responsibility of a field researcher is to provide data that will allow transfer. Dependability is the degree to which there exists confirmation as opposed to a more idiosyncratic presentation of findings. The degree of dependability can be guaranteed, for example, by triangulation. Triangulation is the process of using different methodological strategies and finding overlap and confirmation of findings from
multiple avenues of research. Confirmability refers to the clear presentation of data-gathering methods and their strengths and weaknesses, and discussion of bias and, through its recognition, of the clarity of the data and the concepts that are derived.

Using fieldwork in teaching geography has a long tradition that continues to this day. Perhaps one of the best references for the creation of field experiences is Kent, Gilbertson, and Hunt, who in 1997 outlined the different approaches, preparation, practice, and debriefing. Field study is often one of the activities that attract students to geography, and it is increasingly important that inclusive field experiences are made possible for students of different identities and abilities. While time pressures and budget concerns have no doubt played a role in the decline of fieldwork, the nature of fieldwork in human geography may also be a reason. Fieldwork in human geography depends on more qualitative methodologies, as opposed to the more quantitative approaches used in physical geography. Such methodologies often take researchers many years of experience to develop, and students may not have the tools to make a field experience instructive. It appears that detailed preparation and debriefing are critical to the success of fieldwork by students.

The Future of Fieldwork

Fieldwork today may not necessarily involve outside participation. With increasingly sophisticated technologies being readily available to observe the Earth’s surface from different scales, the notion of what constitutes fieldwork is changing. The roots of fieldwork in contemporary human geography can be found in the explorations that took place in previous centuries. Is virtual fieldwork in the computer laboratory the equivalent of field-based work? Many lament the passage of traditional field-based exploration, but the new virtual explorations allow increased access to students with varying identities and abilities, for example, persons with disabilities, who are unable to navigate a more traditional field-based experience.

Fieldwork is often the face of geography that the public sees, and it is important for geographers to continue to explore the world using whatever technologies are available to understand the human experience better.

Paul Rollinson

See also Chicago School; Fieldwork in Physical Geography; Humanistic Geography; Interviewing; Participant Observation; Positionality; Qualitative Methods; Writing

Further Readings


Fieldwork in physical geography is a standard method in the discipline whereby new understandings of physical phenomena can be obtained most clearly. When combined with other comprehensive mapping tools in the geographic information science (GIScience) laboratory, such as digital elevation models and land cover or land shape data derived from satellite imagery, fieldwork becomes a highly robust means to acquire new
interpretations. Surprisingly, however, in the United States at least, the training of students in the techniques of detailed fieldwork in physical geography is rather limited, although it is taught formally in more universities in Canada and in Europe. The chief reasons for this deficit may be the great diversity of geography and the considerable expense of much modern field equipment, coupled with the difficulty of finding faculty to teach the diverse and interdisciplinary methodologies of fieldwork in physical geography.

Fieldwork in physical geography has been recognized for many years as a central ingredient in the value system of many professional geographers. Some critics have argued that much fieldwork has no theoretical base and that while it may be clearly useful in research, it is not so in teaching; in fact, however, fieldwork in physical geography plays an essential role in both physical geographic research and instruction. A suggested solution to the neglect of fieldwork in much physical geography is improved dialogue between those who are conceptually or theoretically oriented and those who are empirically oriented, as well as between those oriented toward teaching and those toward research. Nevertheless, in spite of numerous publications over the past half-century for improved teaching of field methodologies, problems still occur because of the constant need to recognize new techniques and become skilled in their use. This state of affairs is thus a never-ending quest for improvement of methodologies as physical geographic science marches on.

Methods for Instruction and Research

Empirical and theoretical methods of instruction and research are two sides of the same coin in acquiring geographical knowledge. The three main elements of general geographic research (procedures, techniques, sources of data) range between the empirical and inductive, in the field, for example, and the theoretical and deductive, out of the field. Procedures of research include

1. problem formulation,
2. data collection in the field,
3. statistical and cartographic analysis of the data,
4. formulation of hypotheses, and
5. testing of hypotheses.

The techniques of research are a spectrum of research procedures that generally include

1. the real-world totality of facts,
2. observations and measurements in that real field world,
3. simulation models of that real world, and
4. mathematical optimization models.

The sources of data to accomplish the research task at hand are

1. first and foremost the field observations, whether qualitative observation perceived by sight, hearing, smell, and touch or the many quantitative measurements that should also be made, and
2. archival sources, including maps, aerial photographs, satellite imagery, government records, and the like, which are commonly carried into the field to guide the work.

A third data source can also be the theoretical work, including mathematical or numerical models, but these are rarely useful in the field at the start.

Fieldwork in any discipline is almost always a challenge; in physical geography, the difficulties can be compounded by the very specialized nature of collecting the necessary data in the highly diverse areas of the lithosphere, hydrosphere, biosphere, ecosphere, and atmosphere while at the same time taking care to pay particular attention to the interfaces between these spheres where humans live, such as the soils and landforms of the critical zone. Very few researchers are very knowledgeable in more than one or two of these geospheres, and few can collect reliable data beyond their immediate fields of expertise. Thus, interdisciplinary teams of specialists become necessary to solve interesting field problems. The abilities to fix malfunctioning equipment and to develop alternative methods to “get the data” when some vital piece of field equipment is missing are essential. When field projects involve
complex and physically demanding landscapes in “exotic” foreign countries with tribal people to contend with in a variety of what are generally hoped to be productive and nonthreatening ways, then the requirements for personal skills and cultural sensitivity add further demands on field personnel. Knowledge of foreign languages, the ability to eat odd or unusual foods, and a high tolerance for unforeseen complexities, cultural aggravations, outbreaks of hostilities, bad weather, predatory insects, or aggressive carnivores—all these and more are most helpful in enabling the field researcher to come home with the requisite information and understandings.

Fieldwork in physical geography involves data collection about rock, mineral, and sediment types; measurement of strike and dip of bedrock; stratigraphy; the use of subsurface ground-penetrating radar; collecting information about fossils, rock structures, cosmogenic nuclides, and radionuclides; gathering locational data with global positioning satellite technology; surveying; data collection on weather and climate, glaciers, actively glacierized or previously glaciated terrain, underground water, surficial water, soils, paleosols, vegetation, animals, and geoarchaeological remains; tree ring dating; and geomorphology. This list is a vast panoply of topics across several disciplines, and clearly few geographers have the capability of contributing very much to more than a few of them. Equally clearly, however, working in a multidisciplinary setting where a number of these subdisciplines are part of the mix is something that geographers can fit easily into if they are trained enough to be able to handle the diversity of modern interdisciplinary scientific inquiry.

Fieldwork is best when it has direct and strong linkages to prior training and classroom work, so that the theoretical or the general can be brought to the practical and the specific in the field observation. The ability to discern the essential “signal” in the field from the complex and seemingly random noise of the natural world is an acquired skill that is not easily taught, except by field example. Looking at field landscapes with new eyes for new understandings can be very difficult, however. All too commonly, one’s prior training and experience can also cause one to ignore or gloss over that small bit of field data that just might be the solution to the problem. “I wouldn’t have seen it if I hadn’t believed it” can be a twist of an old adage that keeps field perspectives fresh and inquiry alive. The ability to formulate multiple working hypotheses on the spot in connection to any particular field inquiry is an essential attribute in any field project.

Formalization of field research problems and their methodologies for analytical solutions is a common technique in physical geography that is taught to many students in classes on research methods or field methods. Students are taught to think in logical pathways using well-known inductive and deductive approaches. Formal analytical procedures involving data collection about certain phenomena in the field are commonly established to enable statistically valid sample data sets that will allow robust correlations. At the same time, however, room for serendipitous discovery of the unforeseen in exploration field situations must be allowed as well. One must not be blind to the new and the unanticipated in the field for the essential answer to an unforeseen problem may be inherently obvious in a new field exposure, an unusual configuration of transient phenomena, or discovery of a long-concealed site.

Means of Instruction in Fieldwork

Four means of instruction in fieldwork in physical geography are employed: the field trip, field course, advanced field seminar, and field camp. Field trips for students are a standard pedagogical technique wherein students can be trained to observe and describe aspects of the physical landscape. The best field trips are well structured, with pre- and posttrip meetings and final reports. Field courses, best delivered in the spring semester as the weather improves, are a means to teach the elementary operational techniques of fieldwork, which include observation and sampling, measuring phenomena in different ways and with different equipment, and recording and mapping through writing, photography, and drawing. Students can learn through doing that none should become so engrossed in the mechanics of the techniques that they lose sight of the problem on which they are working. Advanced field seminars, or proseminars, are rare but may be conducted after an introductory field course. The reasons for
devoting time and effort to such a field seminar are the increased variety of field experience that can be offered; the intensity of such a “crash” program; the better insights that can be obtained by focusing in on different problems; the close rapport that develops between people in field situations; and the generation of many new ideas and working hypotheses that emerge from dedicated field seminars at the advanced level.

Although field camps for students in geological studies are an old story and are generally a requirement for most geology majors, such camps are rare in geography programs. Some geography programs have instituted courses in field studies, commonly to provide skills training in geomorphology, meteorology, or environmental studies, but beyond these efforts, fieldwork for geography students is commonly only done in conjunction with professors in the field as a part of graduate student thesis endeavors. Only rarely is more extensive training desired or required to enable students to become better at fieldwork. In the few examples of field camp research programs that are available, some do research on soil and vegetation, water use, geomorphology, wildlife, and fire histories, for example.

Only a very few field camps attempt to integrate field studies of the physical environment with human geography. Themes of field projects have included things such as (a) the natural environment of certain areas; (b) planning and conservation of parks; (c) human perception of the natural environment; (d) the changing location and morphology of human settlements; (e) patterns of land use and residential segregation; (f) the retail location, transport, and logistics; and (g) tourist perception and management. Field camp learning outcomes have included (a) awareness of the integrated nature of physical and human geography; (b) understanding changes in human-environment interaction; (c) knowledge of the evolution of geomorphology and the cultural landscape; (d) understanding of the spatial variation of human activities and settlements; (e) awareness of the impacts of the natural environment on human perception; and (f) appreciation of the relevance of geographic studies. What has also been taught is developing (a) the capacity to identify regularities in the spatial distribution of key physical features; (b) the ability to find and evaluate the location of human settlements and economic activities; (c) the analytical skills to logically link the natural environment with human culture and society; (d) the means to compare and contrast human activities in different locations; (e) critical and independent thinking to evaluate geographic concepts and theories; (f) basic skills in map reading, field observation and measurement, and social survey; and (g) essential skills in the identification and solution of geographic problems.

Basic map reading and skill with aerial photographs and satellite imagery are an essential aspect of most fieldwork. A surprisingly large number of field scientists have difficulty in finding their exact location on maps and aerial photographs in the field. Conversions between the magnetic north and true north are difficult for many people, and overreliance on modern global positioning systems for location mapping can be a severe problem in countries that prohibit that technology. Alternative mapping techniques using compass bearings to prominent features on the landscape in classic resection plotting may be required to complete field projects. If too many hours are spent in the field while one is lost or if one is unable to make any entries in the field notebook for lack of observation, it will clearly detract from good fieldwork.

Numerous challenges beyond sheer intellectual effort can occur for researchers and students in foreign countries doing field research. Linguistics, logistics, culture shock, safety, appropriate clothing, inappropriate hand gestures, long periods of time in the field, camping out, personal hygiene, travel sickness, dating, and partying can all be a source of problems. Student participation objectives in field projects can include acquiring

- conceptual and technological understanding and use of appropriate field equipment by participating in the actual data collection in the field,
- familiarity with various quantitative techniques by using multivariate statistical techniques to analyze spatial and temporal data to answer field questions,
- practical experience in information and product generation by producing new information from existing data products by data integration and spatiotemporal analysis,
familiarity with using remote sensing and GIScience in surveying and solving practical field problems, and
understanding of the background, development, and implementation of a student thesis or dissertation project.

Student activities to accomplish their objectives in field training, whether foreign or domestic, require a balanced approach with regard to theoretical and conceptual formulations, as well as experiential, and technical education and training to accomplish the project. This generally requires participation in a variety of tasks to ensure understanding of field project objectives, conceptual issues, and the actual nature of the fieldwork and development of new skills and problem-solving capabilities. Large field projects will generally require research meetings of all the participants before and after the field experience, usually at conferences, as well as in hotels or universities before heading into the actual field environment. Papers and research proposals are presented at such meetings to provide everyone an understanding of the tasks to be accomplished in the field.

Field Safety and Security

In too many cases, expeditionary fieldwork in physical geography can run aground when the sheer physical difficulty or danger increases so much that attention to the geographic details is necessarily limited. There is a fine line, however, between the too timid soul who withdraws from doing substantive work because of undefined fears of the unknown in the field and the foolhardy risk takers who endanger their own selves, as well as others who might have to rescue them, just to get that rare bit of data. “Life before science” is an adage that some field researchers in physical geography have been known to say before a particularly arduous bit of work in crossing a crevassed glacier or mapping in a dangerous underwater speleological expedition, for example. Expeditionary leaders need to be careful to make good decisions, have alternate plans in mind for emergencies, have knowledge of rescue techniques and rudimentary medical procedures, and have plentiful group meetings to keep everyone on track and out of trouble.

Field safety and security are always major concerns, and over the years, seasoned field analysts almost always accumulate a number of negative experiences that can be quite instructive to others. For example, fieldwork in areas in the United States that are known for certain illegal activities (moonshine production, cannabis cultivation, etc.) can be quite dangerous, as can properties inhabited by well-armed people who are just suspicious of outsiders. In general, spending the extra time necessary to find out who owns the areas of desired fieldwork and seeking permission to go there are not wasted effort. Making introductions and inquiries at the local post office and grocery stores is often productive in this regard. Finding local religious figures to talk to is also a good idea. Security may be a major issue in expeditions to remote areas where many poor people live who may be inclined to steal from you. Automatic meteorological stations or other data collection devices that need to be left in place for a time, for example, may have to be protected by hiring a local person as a guard. Camp security can be further guaranteed by such a procedure, and hiring local porters is always a good idea, although care must be taken in tribal areas to ensure that people from the appropriate local tribe are hired and not those from a nearby antagonistic tribe.

Fieldwork and the Media

Many reporters and photographers in the modern communications media are trained to travel with field teams operating in interesting or exotic locales. Many scientists and physical geographers have a distaste for catering to the needs of the media recording field projects, particularly in arduous field situations or when local media representatives intrude (e.g., when trying to get good camera shots) or ask what the scientists may think are naive or unintelligent questions. Media presence, however, may be an important means by which the status and popularity of physical geography can be increased, particularly when the results are broadcast as television or radio specials or make it to the print media. Some larger granting agencies know well the value of the media in increasing the recognition of the importance of good research, as well as ultimately increasing congressional appropriations to conduct it. The
result is that a certain amount of federal agency funding can be used for publicity in big field projects. This funding is applied for by the media group that wishes to accompany the field scientists. In addition, the National Geographic Society is well-known for its desire to have rights of first refusal for all media endeavors associated with its grants. Physical geographers who wish to avail themselves of greater attention from the various media should seek out the publicity directors of their universities or agencies, who may be able to generate the interest necessary to attract the attention of the media for a field project.

John F. Shroder

See also Fieldwork in Human Geography; Physical Geography, History of; Surveying

Further Readings


**FILM AND GEOGRAPHY**

While interest in film geography can be traced to various authors from the mid 20th century (notably, Eugen Wirth in Germany, J. K. Wright in the United States, and Roger Manvell in the United Kingdom), it was not until the 1980s and early 1990s that a sustained geographic engagement with film occurred. Film is not a *re*-presentation of reality but, rather, is constituted by the industrial practices, social relations, sites, and technologies that produce these cultural products. Film produces a reality effect (a plausible representation of the world that leaves an impression of authenticity) that re-visions, resists, and engages naturalized assumptions of what constitutes reality. Film geographies work to expose these naturalized assumptions, or cultural beliefs that are passed off as natural givens.

The issue of naturalized assumptions became a prominent issue during the late 1980s and was more broadly associated with the crisis of representation. This crisis meant questioning the mimetic belief, or the idea that researchers could achieve absolute realism through representation. Realism is the degree to which any representation *re*-presents what a society believes to be its reality. In other words, the crisis of representation brought into question the ability to which geographic research could accurately re-present reality. The impact of the crisis was the acceptance in geography that exploring the cultural politics in films is just as important as exploring them in urban and natural environments because all are sophisticated social constructions. Broadly speaking, cultural politics refers to the ways in which meaning and identity are constructed, negotiated, contested, and literally mediated through space and representation. As such, geographers are not so much studying re-presentations when it comes to film as seeking to analyze how cultural politics are encoded, reproduced, and perpetuated through mediated space. One way in which film geography can be characterized is under the analytical model of the author-text-reader (A-T-R model). This model derives from literary and film theory and investigates film as an expression of the cultural politics that are circulating within a particular space and time.

**Author-Text-Reader**

Geographers have primarily engaged the cultural politics in the space of the mise-en-scène, or space within the frame of the movie screen. The focus then has been on understanding how social and spatial meanings combine with narrative and audio-visual representations to produce cultural “texts.” With textual, or hermeneutical, analysis, a researcher seeks to interpret and understand the various
meanings of a cultural text. Different theoretical approaches can be brought to bear on the readings of a text; however, film geography has typically focused on three logical sites of investigation: the author, text, and reader. With a focus on the author, analysis is limited to the production of a film and is often focused on auteur theory, where the director’s vision of the meaning within the film is of utmost importance. However, a focus on the author can be expanded to include the cultural era within which the entire production of a film was created.

With a text-centered focus, the researcher becomes an “expert-reader” of the social-spatial meaning embedded within the film. The expert-reader seeks to denaturalize ideologies and expose hidden power relations or social differences within the text. In film, landscape is often a metaphor for a particular type of cultural politics, helping to naturalize ideology, power relations, and social difference. While most expert-reader analysis focuses on the content of the film, some analyses specifically engage with the film’s form. Interest in a film’s form, or more precisely how the visual and audio elements of film are assembled into a representation, has sparked the interest of many geographers. This is especially of importance since many claim that geography is primarily a visual discipline but little has been done to examine just how the visual works to produce geographic knowledge. Film is formed by the frame of the screen, the mise-en–scène, and montage (a technique in film editing, literally meaning “putting together”). Like cartography and landscape painting, film is a product of linear perspective, or a representational system through which one can create the illusion of space on a flat surface. As such, many in film studies, geography, art history, and cultural studies have been interested in film as a modern-day cartography. The central difference between the form of linear perspective in cinema and cartography lies in the angle of the viewer: With film, the camera substitutes for the subject’s eye; in cartography, the orthographic view displaces the subject so that she or he is directly above any point on a map.

With a reader-centered approach, geographers are interested in the reception of a film’s text, or the socially mediated treatment of meaning. With this approach, the object of inquiry moves away from the film and onto the viewer. Inquiry is therefore focused on what is meaningful to the viewer and the affects of reception on an individual or group’s identity, perception, and behavior. At the heart of the affective nature of film is the emotional and (un)intentional response because of the feelings generated by the cultural text. Film has often been called an emotional machine, one that amplifies and modulates affects. These amplifications can occur at various scales (from the individual to the national and the global) and often play on previous feelings resonating within a specific culture and/or era. Affect is more than just a film’s impact on our perception of other cultures and places; it also relates to how we formulate our own identity and how we engage with and understand the world around us.

Chris Lukinbeal

See also Media and Geography; Nonrepresentational Theory; Representations of Space; Symbolism and Place; Text/Textuality

Further Readings


FILTERING

Filtering is a pattern of residential mobility related to changes in the housing stock, especially new construction and devaluation. Filtering is often described with the metaphors of ladders or escalators: Households move up the housing market ladder as dwellings move down the social ladder. Early use of the term included filtering up to denote the former. In recent decades, the use of
the term has been limited to the downward movement of housing units among classes or income groups, associated with the devaluation of dwellings. In housing policy, filtering has long been a key process counted on by advocates of laissez-faire politics. The free market, it is argued, supplies housing for lower-income groups through the process of filtering. It is important to distinguish the phenomenon of filtering, which has been empirically researched for nearly a century, from the ideological assumptions of housing policies based on filtering.

**Filtering and Urban Social Geography**

Filtering as a process of urban social geographic change is commonly associated with the Chicago School of urban studies, particularly Ernest Burgess’s 1925 model of urban concentric zones, and even more so with Homer Hoyt’s 1939 model of sectoral land use patterns, though observations of the phenomenon predate these models. Urban growth takes place largely in the periphery, where the well-off move to new housing, leaving vacancies that become housing opportunities for households lower down the escalator. These models highlight a spatial dimension of filtering as an outward movement of households generated by new construction, as vacancies move in the opposite direction, ending in low-status neighborhoods in the inner city. The Chicago School, employing concepts of invasion and succession borrowed from ecology, emphasized the push factor of immigrants to the city center creating outward ripples in the urban social geographic fabric. Hoyt instead emphasized market mechanisms, the generative force of upper-echelon demand for new modern dwellings in the periphery, and the opportunities this demand spawned through chains of moves.

**Filtering and Gentrification**

Filtering is the opposite of gentrification, both at the microlevel of individual moves and at the scale of neighborhoods, both as a pattern of residential mobility and in terms of investment contra disinvestment in buildings. As a particular event, filtering can be said to take place when the household that moves into a dwelling is of lower socioeconomic status than the household that moves out, while gentrification takes place when the household that moves into a vacancy is of higher socioeconomic status than the household that vacates the dwelling. Though individual changes in occupancy—housing turnover—can be classified as filtering or gentrification, understandings and explanations of these processes of urban change extend beyond the particular, to social structures and mechanisms underlying neighborhood change, housing market dynamics, housing policies, urban politics, and the political economy of space.

Filtering as neighborhood change is characterized by a downward shift in the socioeconomic status of residents through in- and out-migration and by downward movement in relative property values, commonly associated with redlining (designation of the area by financial institutions as ineligible for loans) and disinvestment (e.g., minimal or no maintenance and repair). Gentrification on the other hand is characterized by an upward shift in the socioeconomic status of residents and reinvestment in buildings.

**Neighborhood Life Cycles**

Defined and explained in terms of housing devaluation, filtering is historically part and parcel of neighborhood life cycles. New housing attracts households of higher socioeconomic status than the same housing does decades later, when quality decline due to physical deterioration, style or technological obsolescence, and the rational behavior of disinvestment by property owners and finance capital has filtered the buildings down the housing ladder. While some high-status areas display near-immunity to such life cycles of decline, other areas already of relatively low status when newly built can experience rapid declines. This suggests that underlying filtering is not only a simple neutral demographics of the built environment, from birth (construction) to death (demolition) to rebirth (gentrification through renovation or renewal), but more important, it is the result of societal stratification, social structures, and struggles for power over urban space, not the least over income from urban space. Indeed, land rent is commonly considered a fundamental driving force behind both filtering and gentrification.
Vacancy Chains

An embryo to the concept of vacancy chains was formulated in 1885 in Ernest George Ravenstein's seminal Laws of Migration. Ravenstein noted chain patterns of migration up national hierarchies of central places, those moving higher up in the hierarchy leaving vacancies filled by others moving from rural centers lower down in the hierarchy. Filtering is a similar pattern but within the socio-economic hierarchy of urban housing markets.

Figure 1 depicts the time-geography of a vacancy chain, sometimes called a chain of moves. A new dwelling is completed at Time 1 (Vacancy position 1). The chain starts with a move out of an existing dwelling. This process is repeated with each new move, resulting in the formation of vacancies that are filled by subsequent moves.

Figure 1 The filtering process. Time-geographic sketch of a vacancy chain initiated by a newly built dwelling, entailing four moves between Time 1 and Time 5 and ending due to a move from the parental home outside the urban parental market.

Position 1). At Time 2, a family of four moves in, leaving their previous dwelling vacant (Vacancy Position 2). At Time 3, a family of three moves into Vacancy 2, leaving their previous dwelling vacant in turn (Vacancy Position 3). Later, at Time 4, a couple moves in. The dwelling they left (Vacancy Position 4) is moved into at Time 5 by a young person moving away from the parents’ home in another region.

New vacancies in a housing market arise either through change in the housing stock (new construction, subdivision of housing space, or conversion from nonresidential) or through change among households (e.g., death of a household, moving together to share a dwelling, or out-migration to another region). The new vacancy may pass through a number of dwellings as households use openings in the housing market, moving to satisfy their demands for housing characteristics. Ends of vacancy chains may be due to changes in the housing stock (demolition, conversion to nonresidential, merging of housing space, or long-term vacancy) or to changes among households such that the dwelling moved from is not vacant after the move (moving from parental home, divorce or separation, acquiring second home) or involves a new vacancy in another region (in-migration).

Vacancy chain studies that include data on the socioeconomic status of households reveal the extent of filtering. Most studies have focused on vacancy chains initiated by new construction, for the purpose of testing the assumption that construction catering to the demand of the economically well-off can meet the demand of lower-income groups as well. Some studies have instead aimed to evaluate consistency between the stated intentions of housing policies and their actual impact.

Residential mobility provides many more opportunities in a housing market than does the volume of new construction alone. The research is also highly consistent in showing that filtering is not effective in improving housing conditions for lower-income households. Laissez-faire housing policy commonly assumes that filtering works to the benefit of lower-income households. There is no empirical evidence for this assumption. Under conditions of laissez-faire, filtering benefits middle- and upper-income households, only very marginally reaching the lower-income submarkets. Benefits to lower-income households tend to be greater where new construction occurs in modest-quality submarkets. This requires housing policies that stimulate specific forms of new construction that benefit lower-income households.

Eric Clark

See also Chicago School; Gentrification; Ghetto; Housing and Housing Markets; Housing Policy; Hoyt, Homer; Real Estate, Geography and; Rent-Gap; Urban Spatial Structure

Further Readings


Research on Filtering as a Housing Policy

In 1949, Richard Ratcliff concluded that substandard housing was the end product of filtering: Filtering produced the very problems housing policies sought to remedy. Filtering came to be critiqued as a euphemism for slum formation. For more than 60 years, housing economists and urban geographers have empirically researched filtering and shown that filtering is an important process through which housing demand is met.

Filtration

Filtration is the process by which solid particles dispersed in liquid or gaseous fluids are separated from the fluid. This process is done for two main purposes: (1) removal of suspended solids and (2) thickening. Removal of suspended solids is generally done for the purposes of treatment or remediation of air or water to improve the
quality of the fluid, and thickening is done as a sludge-processing technique. The mechanism by which filtration occurs is a mechanical or physical operation wherein some type of material or medium such as filter screens, filter paper, or some granular material such as sand or other materials is interposed and then gravity or pressure-pumping processes are used to separate the solids from the fluid as they are caught as a retentate and the fluid passes through.

**Air Filtration**

Smokestacks, garbage incinerators, and other producers of potentially noxious emission are commonly subjected to various types of chemical and water spray scrubbers and baghouse filters to trap undesirable gaseous and particulate pollutants. Homeowners are familiar with replaceable fiberglass air filters that are installed in their home air conditioning or forced-air heating systems.

**Water Filtration**

Two main types of water filters are in use: (1) granular-medium filters and (2) surface membrane filters. Both types are designed to remove undesirable materials or contaminants, but the membranes can achieve very fine filtration down to 3 Å (angstroms; 1 Å = 10⁻¹⁰ meter), which is at the atomic level.

Granular-medium filters are designed with various configurations of materials such as sand, gravel, anthracite coal, activated charcoal, and other compounds. In the filtration process, the water or wastewater is applied to the top of the filter bed so that the suspended matter in the water is removed in various ways, including mechanical and chance-contact straining; inertial impaction and sedimentation; interception; adhesion and absorption, or the sticking of particles to the filtrate; and flocculation, wherein the particles clump together and are too large to pass through the filter’s openings. At some point, the granular-medium filters may become clogged with particulates and have to be backwashed or back-flushed with water or air so that undesired particulates can be disposed of.

Semipermeable-membrane processes of filtration involve separation effected by water passing through the membrane as osmosis or hyperfiltration. The opposite process, wherein solute molecules and ions pass through the membrane, is called dialysis, which is familiar to many as the medical procedure of blood dialysis for those suffering from kidney failure. Membrane processes may be used to desalinize water, treat industrial wastes, or recover economically valuable materials such as precious metals from waste streams. Reverse osmosis is a case in which pressure is applied to a material such as saltwater to drive water without salts through the membrane, leaving the saltier water behind.

Solids and sludge left over after filtration processes need to be further processed and disposed of because they are among the most difficult to deal with in wastewater management. This is because the sludge contains much of the original offensive material of the incoming liquid, only a small part of it may be solid matter, and the waste biological material is organic and will decay. Further filtration may remove more water to thicken the remaining waste. This can be accomplished by vacuum filtration, heating, freezing, pressing, centrifuging, or simple gravity thickening. Drying beds and lagoons may also be employed.

John F. Shroder

See also Agrochemical Pollution; Atmospheric Pollution; Water Pollution

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**Finance, Geography of**

Financial geography is a recent subdiscipline within economic geography that is increasingly being recognized as an autonomous research field. While initially the field merely replicated the research objectives of economic geography more generally and aimed to answer questions related to the spatial distribution of finance, more recent contributions to the literature claim that the current rise of financial markets presents important meta-theoretical challenges to the discipline as a whole. In that regard, the fate of the discipline is clearly linked to recent economic transformations, in particular the coming about of a truly transnational financial system that has proven to
be highly prone to booms and busts. This entry briefly discusses the economic preconditions for the rise of financial geography. It then sketches the main strands of research and outlines recent developments within this literature.

The Geography of Finance and the Birth of Financial Geography

“Money makes the world go round!” This phrase neatly encapsulates the intricate link between money and space. Of the three functions of money—storing value, serving as a unit of account, and serving as a medium of exchange—the latter two impinge directly on geography. By providing a single standardized measure for the value of different goods and services, money facilitates the exchange between strangers, annihilating space and crossing cultural, social, and physical boundaries. As such, money is one of the great “space-shrinking” and “border-crossing” techniques of mankind. However, a geography of finance, in the sense of a systematic study of the spatial distribution of financial value production, only came into being when providing money, forwarding capital, intermediating exchange, and settling accounts became specialized economic functions. Banks, brokers, and exchanges owe their existence largely to the increasing division of labor that is the hallmark of modernization. However, these functions were not spread evenly over space but appeared to follow the development of the urban network and the hierarchy of marketplaces it implied. In other words, from the 17th century onward a complex network of local, national, and transnational financial centers came into being that has since become a self-standing object of investigation of what could be termed “financial geography.”

Initially, the study of financial centers and, more broadly, the spatial distribution of financial flows, markets, and products was not exclusively a geographical object of study, even though older geographical theories such as “central-place” theory were widely used to explain the multiscalar nature of financial center networks. During the 1950s, 1960s, and 1970s, the study of the geography of finance was very much a niche topic that was largely the preserve of isolated economists and some historians. Still a classic is Charles Kindleberger’s 1974 study of the “formation of financial centers,” which, tellingly, was presented by the author as a “study in comparative economic history,” as its subtitle read.

This changed from the 1970s onward, when deregulation, liberalization, and privatization as well as technological changes (the start of the rise of information and communication technologies) unleashed a torrent of liquidity and financial innovation. A financial and economic crisis as well as 6 years of war on a global scale had largely undone the border-crossing entanglements of the “first wave of globalization” that ended so brutally in the trenches of Flanders in World War I. During the first three decades after World War II, exchanges, banks, brokers, and insurers had mainly served a national clientele. Stepwise globalization, starting in production and consumption markets, facilitated a hesitant international deployment of financial functions by some of the largest financial players. The wish to grab these new market opportunities and effective policy lobbying, as well as the demise of the Keynesian underpinnings of the postwar regulatory regime, resulted in the gradual liberalization of national financial markets and the construction of the transnational financial system of today.

Disciplinary Perspectives

With the rise of financial markets as the new centers of economic control and the transformation of financial firms from intermediaries into self-standing sources of economic activity, the research agenda of the geography of finance underwent radical changes in the 1980s and 1990s. Most notable was the influx of economically trained scholars who used econometric modeling techniques to explain (and predict) price formation in integrated financial markets. Now known as “finance,” a prestigious economic subdiscipline that generated a number of Nobel Prize winners whose prize-winning theorems have become common fare for traders worldwide, it has become highly implicated in the workings of the financial markets. A development that is captured by the term performativity is that finance does not provide a description of real existing financial markets but has instead stood at the cradle of their construction. Or in the telling simile of Donald
MacKenzie, “Finance is not a camera but an engine.” While the perspective of the financial world is highly influential, it does not contain much geography. Geographical phenomena, such as the famed “home bias” of investors, who appear to invest most of their capital in firms of the same nationality instead of diversifying their assets over different countries, are seen as market anomalies that raise interesting questions about investor irrationality but not as geographical issues in their own right.

Second, because of their increasing economic importance and the impact they have on the wider community, financial markets and financial centers have increasingly become objects of policy interventions and have, as a result, spawned a huge amount of quasi-academic reports and rankings. Very popular among policymakers, practitioners, and pundits, “global city indices” give visual overviews of the hierarchical ranking of global, regional, national, and local financial centers. Here we clearly see traces of the older central place theory tradition, for the implication is that financial centers, although located at different geographical scales, are embedded in a global network of central places that is spatially structured. Combined with the notion that financial markets have become truly global and have largely escaped the gravity of the state, this has given rise to what is called “relational geography”; that is, to explain what occurs in any one node of the network, one has to trace its ever-changing relationship with other nodes. Influential examples of this approach are the works of Saskia Sassen and Peter Taylor.

The rise of finance has also caught the attention of economic sociologists and researchers who work in the tradition of the social studies of finance. Most of this research is of an ethnographic or microsociological nature. Although it provides meticulously detailed descriptions of trading floors, trading rooms, bank-client interactions, and the technological interface between traders and the virtual market, it lacks an overarching research agenda. Since financial markets are taken to be the most lifelike realizations of the neoclassical economic paradigm, demonstrating the socially and culturally embedded nature of trader interactions is seen as a disconfirmation of the universal validity of neoclassical assumptions. However, it is unclear what should follow from this disconfirmation. If the economic perspective is falsified, how should we explain its durability, and what should replace it?

A fourth take on financial geography can be found in the financial-center literature. Building forth on the Marshallian notion of industrial districts that he developed in the late 19th century, which hang together on so-called untraded interdependencies, or positive externalities, an increasing number of economic geographers have shifted their research focus from manufacturing industries to producer service sectors such as advertising, architecture, film production, fashion, and the creative industries more generally. This shift is largely informed by the effects of deindustrialization and the rise of metropolitan service economies. Part of this agenda is a newfound interest in the concentration of complementary financial activities in so-called financial centers. In contrast to the relational approach in geography, the emphasis is less on the relational network between financial centers and more on the microgeographical linkages between firms and employees within financial centers. Detailed empirical work is used to answer classical geographical questions concerning colocation and proximity and their functional advantages to different agents. However, given the microgeographical focus of this agenda, it frequently loses sight of processes that play out at broader scales.

A final stream of thought comes from comparative institutionalism, where different financial systems are seen to serve crucial aggregating, mobilizing, and allocating functions. The locus classicus of this mode of reasoning is Alexander Gershenkron’s 1962 *Economic Backwardness in Historical Perspective*, which distinguished between bank-based and market-based financial systems and related these differences to different growth trajectories. While this approach is rooted in a comparative static and originally failed to see beyond the nation-state, more recent contributions increasingly focus on change and transnational as well as subnational developments. Be that as it may, the hallmark is and remains its focus on institutions and their behavioral effects. While financial markets can be seen to be the most transnational markets of all, this does not imply a regulatory void, as a growing body of comparative institutionalist literature demonstrates. Hence,
the institutional emphasis of this type of literature provides a useful antidote to the tendency of perceiving finance and financial markets as free-floating entities.

**Toward a Synthesis?**

Currently, the period in which these different research strands could exist in blissful ignorance of one another is ending. There is an increasing awareness that the complexity of the object warrants a multimethod, multitheoretical, and ultimately multidisciplinary approach. The most promising new works in financial geography wed the agent-based approaches of the Marshallian agenda and the social studies finance to a more structure-based approach that focuses on the agency effects of institutions and regulations and add to that a relational perspective that zooms in the interaction effects between different nodes in the globe-spanning network that is the transnational financial system. As such, these works clearly perceive the weaknesses of the different disciplinary perspectives listed above and aim to use the strengths of the one to overcome the failings of the other and vice versa. A fine example of such a multitheoretical approach is found in the works of the Oxford geographers Gordon Clark and Dariusz Wojcik.

Part of the reason why it took such a long time to perform such a synthesis is that the study of the geography of finance has only gradually liberated itself from the normative “a prioris” that have too long hindered sober description and analysis. During the long period when financial geographers were working in the shadow of Marxian political economy, descriptions and explanations were too much colored by normative assumptions that were disguised as theoretical premises. Since the mid 1990s, a growing number of younger scholars, accompanied by some less dogmatic elders, have finally succeed in crawling out of that shadow and are now on the verge of creating an invigorating research agenda that cries out for its own, as yet nonexistent, publication platforms.

Whether that will ultimately result in a true synthesis, in the sense of a new theoretical paradigm with universal validity claims, is unclear. Attempts to do so may well alienate scholars who feel their approach to be at odds with such a synthesis, resulting in a breakdown of the interdisciplinary cooperation that is now being conducted. Presumably, given the complexity and dynamic nature of the object, cross-disciplinary collaboration is the most we can hope for.

_Ewald Engelen_

*See also* Economic Geography; Money, Geographies of; Telecommunications and Geography; World Cities

**Further Readings**


**FISHER, PETER (1955– )**

Peter F. (Pete) Fisher is professor of geographical information in the department of geography at the University of Leicester, United Kingdom. He is a prominent geographer and geographic information scientist best known for his long tenure as editor (1998–2007) of the *International Journal of Geographic Information Science (IJGIS)*. His faculty appointments have been at Kingston...
FISH FARMING

Farming a single species of fish through industrial aquaculture processes, as opposed to hunting marine life in the wild or integrating fish farming with subsistence agriculture as is done in Asia and Africa, is a relatively new idea. Farming marine species such as Atlantic salmon and cod emerged slowly in the 19th century, prompted initially by localized overfishing, fluctuating fish landings, and increasing demand from merchants. The Atlantic salmon was domesticated for industrial production in Norway after wild salmon

Polytechnic, Kent State University, the University of Leicester, and City University London. He holds a PhD in geography from Kingston Polytechnic University, MSc in pedology and soil survey from Reading University, and BSc in environmental science from the University of Lancaster.

After an early specialization in physical geography (mid-Quaternary history, soils studies, and archaeological investigations), Fisher turned permanently to computer applications in geography and in geographic information science in particular. His research interests include uncertainty in geographic information, visibility analysis, and the social impacts of geographic information technology. His publications address uncertainties associated with algorithm design and implementation, database errors, and misunderstandings associated with the actual questions being asked. He has studied probabilistic models of uncertainty in soil maps and elevation models and fuzzy models of uncertainty. Most recently, he examined Type 2 and Type \( n \) fuzzy sets in the context of recognizing topographic features.

From 2003 onward, Fisher expressed a strong professional interest in the societal impacts of geographic technologies. In particular, he has focused on privacy, human tracking, and geoslavery. His writings on these topics have led the field in attempting to foster national and international debates on benefits and risks.

As editor of *IJGIS*, Fisher had a notable impact on the emerging field of geographic information science. In the 1980s, geographic information systems (GIS) operated primarily in the domain of specialists in universities, government offices, and corporations. As he took the helm at *IJGIS* in 1994, GIS was in the early stages of its transformation to the popular status that it enjoys today. Global positioning systems (GPS) and Google Earth became household words, while *IJGIS* advanced the science on which they were based. More than 600 articles were published during his tenure at *IJGIS*.


Jerome E. Dobson

See also Geoslavery; GIScience

Further Readings


declined due to overfishing and other anthropogenic assaults. After World War II, the technologies of war were applied to finding and catching fish worldwide. Factory freezer bottom draggers, which scrape the ocean’s floor collecting everything in their path, drift nets and monofilament gill nets, hydraulic winches, sonar, radar, diesel engines, and other industrial fishing technologies drove 75% of global fisheries to the brink of commercial extinction by the dawn of the 20th century.

In the wake of the decline in global wild fisheries, industrial fish farming has positioned itself as the solution to the global food crisis and overfishing. The resulting “Blue Revolution,” termed so by the industrial aquaculture industry to refer to the domestication and cultivation of aquatic plants and animals for profitable sale in global markets, promises to transform wild marine fish into docile domesticates and fish hunters into harvesters. As commercially fished marine species continue to face extinction in the wild due to overfishing, pollution, global climate change, and a host of other anthropogenic assaults, “culture” has emerged as a keyword in global fisheries. Like the terrestrial dreams and grandiose visions of their Green comrades a half-century earlier, Blue revolutionaries advocate the application of scientific expertise, industrial technology, and transnational capital in their oceanic culturing projects. These culturing projects influence and seek to transform human identity and ways of living as much as they do the genetic makeup, behaviors, and metabolism of the wild fish species that are targeted for industrial domestication and farming.

While marine fisheries have been highly capitalized and industrialized since World War II, it is only since the 1980s that the marine environment has undergone an agricultural transformation such as the one that has been well established on land for many thousands of years.

The meaning of culture includes
1. the taming, domestication, and husbandry of wild plants and animals;
2. the development or civilizing of people presented as savage and barbarous by colonizers and administrators; and
3. the anthropological description of distinct human ways of life.

Culture in its original sense referred to cultivation, a process whereby wild plants and animals are brought into a sphere of human influence where stewardship, husbandry, and caretaking take place and cultivator and cultivated each become adapted to conditions and terms dictated by human interests. The various normative and symbolic associations with taming and bringing wildness into the domestic human sphere are complex, ranging from nurturing to exploitation. This complex of meanings spills over into the connotation and operation of the other two meanings of culture discussed by Raymond Williams.

Processes of culturing and domestication have framed relations that extend well beyond human relations with wild plants and animals to include the development of hierarchically related groups of people in the context of the civilizing projects of imperial colonization, as well as transformative relations within societies. Contemporary industrial fish-farming projects are often tied to international development, where the production of export commodities is promoted by international banking institutions, state development agencies, and global aid and investment funds.

Romantic and resistance movements against the domestication of wild fish and the subjugation of human otherness and difference grounded in hierarchical dualisms have also deployed “culture.” In this third meaning, culture stands for diverse and unique ways of living that are valued intrinsically without the need for improvement or eradication through taming, domestication, civilizing, or development. The three meanings of culture provide a rich tapestry of relations among and between fish and fishing peoples. What the Blue revolutionaries promise to achieve through industrial fish farming is a complete replacement of harvesting of endangered wild fish with
improved domesticated fishing systems. All three meanings of culture associated with fish farming imply different relationships with nature spanning domination, stewardship, and coevolution within natural thresholds. It remains to be explored how some of these relations play themselves out with respect to the culturing of fish and the fishing people in different places worldwide.

Dean Bavington

See also Aquaculture; Domestication of Animals; Marine Aquaculture; Sustainable Fisheries

Further Readings


Fjords

Fjords are one of the more prominent and spectacular landforms found on Earth, formed in areas that have been exposed to extensive glaciations. Fjords are glacially carved valleys, commonly termed U-shaped valleys or glacial troughs, that have been flooded by the sea during and after the glaciers that formed them retreated. Thus, they demonstrate the erosive powers of outlet glaciers draining continental ice caps and ice sheets. This entry discusses the location of fjords, characteristics of their profiles, and processes of formation.

Fjords are channels of formerly radiating outlet glaciers that drained large continental glaciers during the ice ages, as seen in Greenland and Antarctica today. Fjords are therefore only found along high-latitude coasts on both hemispheres. Among countries well known for their fjords and fjord regions are New Zealand, British Columbia, Chile, Greenland, Alaska, and Norway. Two Norwegian fjords, Geirangerfjord and Naeroyfjord, are considered archetypical fjords and are therefore on UNESCO’s World Heritage List.

Sognefjorden, in Norway, may serve as an example of the size, characteristic features, and dimensions of a fjord system. Sognefjorden cuts its way more than 200 km (kilometers) from the west coast of Norway into the mountain area of Jotunheimen. The maximum depth (1,308 m [meters]) is found more than 50 km inland, giving rise to an overdeepened longitudinal profile (see Figure 1). Adjacent mountains peaks, rising more than 1,700 m above sea level, give rise to extreme reliefs. Commonly, a fjord system consists of several tributary fjords and valleys that coalesce toward the coast, producing a dendritic pattern.

The rate at which glaciers erode depends on the ice thickness and flow velocity; hence glacier troughs will not form in a flat landscape with a uniform ice thickness. Fjord dimensions are thought to be adjusted to the volume of ice that is discharged during maximum glacial conditions. The result is a wide, steep-sided valley, a shape that efficiently conveys glacier ice by sliding and deformation from the source area to lower altitudes, where there is a net ablation. The typical U-shape can be observed in some deep, narrow fjords, but more often the cross-profile of glacial troughs has a parabolic shape, which is favored by ice flow. However, not only glaciological parameters control the trough cross-profile, but the rock mass strength is also found to be an important controlling factor of cross-profile development.

Glacial troughs are likely to have developed in preglacial valleys, which are deepened and widened, while the adjacent mountain plateaus may show limited signs of glacial erosion. The pattern and size of the fjord system are therefore largely inherited from the preglacial landscape. However, ice divides of continental ice sheets may not coincide with the underlying watershed; thus, fjords may drain ice from substantially larger areas than the preglacial fluvial catchment.
It has also become increasingly evident that linear geological structures in the bedrock, for example, faults, strongly control the development of glacial troughs. It is suggested that in Patagonia outlet glaciers from repeated glaciations have widened and deepened preexisting geological structures, with less effect on the intervening landscape.

Seen from space, or in a map view, glacial troughs tend to be more linear than those carved by rivers. This relates to the properties of ice compared with water, preventing it from making the same steep turns that rivers are able to do. Thus, a glacier tends to straighten the fluvial preglacial valley.

Glacial fjords also have characteristic irregular longitudinal profiles, consisting of overdeepened troughs with intervening thresholds. An overdeepened trough is a landform where the slope near the mouth is reversed. In other words, the trough is deepest in the middle and shallower toward the ends. This is clearly seen in many fjords, which can be more than 500 m deep in the central part and less than 100 m deep at the fjord mouth. Although ice has a lower density than water and will float, glaciers may grow thicker than the water depth they enter. When the ice thickness exceeds the water depth by approximately 10%, the ice is grounded and can erode the fjord bed. Fjords with depths of many hundreds of meters
FLASH FLOODS

thus provide evidence of great ice thicknesses and the fact that fjords conveyed huge volumes of ice during the maximal glacial conditions.

Glacier erosion takes place as glaciers slide over their bed, tearing loose particles from the underlying bedrock and abrading the bed by dragging rock particles along their base. Although glaciers may produce huge quantities of sediment each year, glacier erosion is a slow process taking place over large areas. Glacier erosion is estimated to proceed at rates of the order of millimeters per year. It thus follows that fjords are old landscape elements that have formed during multiple glaciations.

Geir Vatne

See also Glaciers: Continental; Glaciers: Mountain; Landforms

Further Readings


FLASH FLOODS

Flash floods occur when water levels rise rapidly and inundate low-lying areas. The United States National Weather Service defines flash floods as floods that occur within 6 hours of their cause, which may include heavy rainfall, ice dam breakage, and dam or levee failures. Flash floods cause minor to severe damage, injury, or death, and often disrupt transportation systems. Although some regions are more likely to experience flash floods than are others, they can occur anywhere in the world.

Flash floods often occur when heavy rain falls on less permeable surfaces such as clay soils, soils already saturated with water, and concrete. Urbanization therefore contributes to flash flood hazards in two ways. Instead of infiltrating the ground, the water flows over land surfaces and through streets, increasing human exposure to flash flood hazards as well as the potential for damages and injuries.

Flash floods are a major geomorphological force that erodes soil and rock to create and
FLASH FLOODS

Deepen canyons, arroyos, and steep valleys, particularly in arid or semiarid regions. Deeper channels confine water and prevent it from spreading across the surface, enhancing the risks associated with flash floods. In a canyon flash flood, the water may appear suddenly and without warning from an unseen source upstream. In such cases, the optimal method of escape is to climb to higher ground, although this is not always possible and many hikers find themselves in danger each year. The Big Thompson River flood of 1976 is one example of a canyon flash flood, in Colorado, that resulted in the deaths of 146 people.

Infrastructural failures may include naturally occurring structures such as ice dams as well as human-made structures such as dams or levees. Although infrastructural failures are often associated with heavy rainfall, this is not always the case. As a result, such flash floods are extremely difficult to predict and have the potential to devastate extensive areas.

Ice dams are created when water is retained behind a wall of ice. Water pressure builds up behind the dam and may cause it to break, flooding areas downstream. Ice dam failure is a typical event in spring, when rain and warm temperatures combine to melt snow and ice into the reservoir while simultaneously weakening the ice dam. Loss of life from ice dam flash floods is low despite the high frequency of these events because they are relatively predictable. A thaw prediction after one of the heaviest ice accumulations on the Yellow River in China led authorities to evacuate 13,000 people in March 2008. The ice dam burst, but no casualties were reported.

Dam and levee failures present a difficult problem for water managers and residents alike. These types of infrastructure are designed to prevent or
alleviate flooding and usually allow greater development within a floodplain, bringing more people and property under the threat of flash floods. When they do fail, the subsequent flash floods are often devastating to communities downstream because of their suddenness and severity. In 1975, Typhoon Nina produced more than a year’s average of rain over the Banqiao Reservoir in China, causing the Banqiao and 61 other dams to fail. Entire communities were destroyed, leaving approximately 26,000 dead from the flash floods and over 100,000 more dead due to subsequent waterborne disease and famine. The storm surge from Hurricane Katrina in 2005 breached 53 flood control levees and caused another 28 to fail outright, rapidly flooding New Orleans and leaving more than 700 dead in the city from flooding alone.

Flash floods frequently cause severe and extensive damage to roads, buildings, and vehicles and frequently undermine infrastructure designed to protect people from danger, such as bridges, culverts, dams, and levees. Swift water often erodes submerged land surfaces to a great extent, which may not be visible to onlookers on account of turbidity. Rapidly flowing water also has the power to dislodge rocks, boulders, branches, trees, and even entire buildings; carry the debris downstream; and damage or demolish anything in its path.

Apart from the damage to infrastructure caused by flash floods, people are vulnerable to the floodwaters themselves. Thousands of people are killed or injured by flash floods each year due to drowning or the debris flowing within the water. In the United States, flash floods kill approximately 100 people per year, more than any other weather-related hazard except for extreme heat. Nearly half of those deaths are of people trapped inside or attempting to escape from their vehicles after driving through high water. Thousands more require swift rescue from emergency response teams. To reduce the number of deaths and injuries, local, state, and federal flood risk management agencies have launched numerous public education campaigns, such as “Turn Around, Don’t Drown” from the National Weather Service. Arizona state law has made driving into high waters illegal, and punishment includes fines to cover rescue costs. The National Weather Service also provides public alerts that include flash flood “watches,” which indicate the possibility of flash flooding for a given area, and “warnings,” which indicate that flash floods are occurring or imminent in a given area.

The Storm Events database from the United States National Climatic Data Center compiles flash flood data collected by National Weather Service weather forecast offices as reported by media sources and “spotter” networks formed of both officials and citizens. As a result, the reports are incomplete and generally concentrated in urban areas, particularly those with weather forecast offices. However, Storm Events provides the most comprehensive collection of flash flood data that includes meteorological and hydrological information as well as casualty and damage statistics.

Ashley R. Coles

See also Environmental Perception; Floodplain; Floods; Land Use and Cover Change (LUCC); Natural Hazards and Risk Analysis; Risk Analysis and Assessment

Further Readings


Flexible production, also called post-Fordism, refers to the forms of manufacturing that began to take shape and eventually become dominant throughout the late 20th century. In contrast to Fordism, flexible production allows goods to be manufactured cheaply but in small volumes as
well as large volumes. A flexible automation system can turn out a small batch, or even a single item, of a product as efficiently as it can a mass-assembled commodity.

Flexible production appeared, not accidentally, at the particular historical moment when the microelectronics revolution began to revolutionize manufacturing; indeed, the changes associated with the computerization of production in some respects may be seen as the response of capitalists to the crisis of profitability that accompanied the petro-crises. Flexible production also reflected the imperative of firms to increase their productivity in the face of rapidly accelerating, intense international competition.

The most important aspect of this new, or lean, system is flexibility of the production process itself, including the organization and management within the factory, and the flexibility of relationships among customers, supplier firms, and the assembly plant. In contrast to the large, vertically integrated firms typical of the Fordist economy, under flexible production, firms tend to be relatively small, relying on highly computerized production techniques to generate small quantities of goods to be sold in relatively specialized markets. Microelectronics, in essence, circumvented the need for economies of scale.

The classic technologies and organizational forms of post-Fordism include robots and just-in-time inventory systems. The Japanese developed just-in-time manufacturing systems shortly after World War II to adapt U.S. practices to car manufacturing. The technique was pioneered by the Toyota Corporation (and hence is sometimes called “Toyotaism”), which obviated the need for large, expensive warehouses of parts (the “just-in-case” inventory system). Just-in-time refers to a method of organizing immediate manufacturing and supply relationships among companies to reduce inefficiency and increase time economy. Stages of the manufacturing process are completed exactly when needed, according to the market, not before and not later, and parts required in the manufacturing process are supplied with little storage or warehousing time required. This system reduces idle capital and allows minimal investment so that the capital can be used elsewhere. The manufacturing run proceeds only as far as the market demands.

Inventories are very small and are only replenished to replace parts removed downstream. Workers at the end of the line are given output instructions on the basis of short-term order forecasts. They instruct workers immediately upstream to produce the part they will need just-in-time, those workers in turn instruct workers upstream to produce just-in-time, and so on. Post-Fordist approaches to production came to dominate much of the electronics sector, automobile production, and the mini-mills of the steel industry.

Flexible production is closely associated with vertical disintegration and increased subcontracting rather than “in-house” production. Many firms engaged in significant “downsizing” in the 1980s and 1990s, often ridding themselves of whole divisions of their companies to focus on their “core competencies.” A large number of companies reversed their old principles of hierarchical, bureaucratic assembly-line (Fordist) processes as they switched to customized, flexible, consumer-focused processes that can deliver personal service through niche markets at lower costs and higher speeds.

In the process, the use of subcontracts accelerated rapidly. Firms always face a “make or buy” decision, that is, a choice of whether to purchase inputs such as semifinished parts from another firm or to produce those goods themselves. Under the relatively stable system afforded by Fordism, most firms produced their own parts, justifying the cost with economies of scale, which lowered their long-run average cost curves. Under post-Fordism, however, this strategy is no longer optimal: Given the uncertainty generated by the rapid technological and political changes of the late 20th century, many firms opted to “buy” rather than “make,” that is, to purchase inputs from specialized companies. This strategy reduces risk for the buyer by pushing it onto the subcontractor, who must invest in the capital and hire the necessary labor.

A key to production flexibility lies in the use of information technologies in machines and operations, which permit more sophisticated control over the process. With the increasing sophistication of automated processes and, especially, the new flexibility of the new electronically controlled technology, far-reaching changes in the process of production need not be associated with increased
scales of production. Indeed, one of the major results of electronic computer-aided production technology is that it permits rapid switching from one process to another and allows the tailoring of production to the requirements of individual customers. Traditional automation is geared to high-volume standardized production; flexible manufacturing systems are quite different. In the business world, flexibility is based on customization of output to individual needs and wants; higher quality and higher value added; rapid response and delivery; and improved service and follow-up. Instead of greater capital investments in infrastructure and machines, software and marketing databases allow firms to estimate the needs of customers and identify niche markets. Such software allows firms to produce in “short runs” for market niches, quickly changing markets without setup costs and avoiding delays of assembly-line systems.

As interfirm linkages grew rapidly in the 1980s, many firms found themselves compelled to enter into cooperative agreements with one another (e.g., joint ventures). Quality control, that is, minimizing defect rates, became very important. Many firms succeed in this environment by entering into dense urban networks of interactions, including many face-to-face linkages, ties that “noneconomic” factors such as tacit knowledge, learning, reflexivity, conventions, expectations, trust, uncertainty, and reputation figure heavily. Geographically, therefore, flexible production is closely associated with the dense concentrations of “high-technology” firms that emerged in the late 20th century, including California’s Silicon Valley, Italy’s Emilia-Romagna region, Germany’s Baden-Württemberg, the Danish Jutland, and the British electronics region, centered in Cambridge. In such contexts, firms can substitute agglomeration economies (or external economies of scale) for (internal) economies of scale achieved by producing in large quantities.

Barney Warf

See also Agglomeration Economies; Electronics Industry, Geography of; Fordism; High Technology; Industrial Districts; Labor, Geography of; Regulation Theory

Further Readings


Flocculation is the process by which small primary particles in an aqueous suspension join to form a larger secondary, or composite, particle. Although the term *composite particle* encompasses all multigrain suspended sediment particles, the term *flocculation* refers to all processes by which suspended particles are brought together in water to create larger units termed *flocs*. This distinguishes flocs from *aggregates*, which are composite particles formed in a nonaqueous medium. In engineered systems, flocculation has been referred to variously as aggregation, agglomeration, and coagulation, but the result is still the formation of larger composite particles. In natural systems, flocculation is known best in estuaries and open-ocean environments but has also been documented in freshwater fluvial and lacustrine environments. Flocculation is an important aspect of water quality in both natural and engineered systems, as the floc settling velocity must exceed the settling velocity of the constituent particles due to an increase in mass and as flocs are more easily filtered from water than are primary particles.

Flocculation is a dynamic process controlled by a variety of physical, chemical, and biological factors. The two necessary conditions for flocculation are collision of primary particles and subsequent cohesion. The mechanisms responsible for collision include turbulence within the suspending liquid and differential settling of the particles by size, shape, or
FLOODPLAIN

A floodplain is one of the ubiquitous fluvial features found along major rivers. It is a wide, flat plain of alluvium on either side of a river extending to the base of a valley that is seasonally inundated. Inundation may originate from overbank flow due to the high amount of rainfall or spillage from dams (see Amazon and White Volta photos). Geomorphologically, actively inundated areas are the composite fringing floodplains of rivers located near the main channel.

A floodplain is a complex assemblage of landforms (Figure 1) including channel features such as bars; channel edge features such as banks, benches, knickpoints, and levees; and features such as old channels (oxbow lakes), old levees, back swamps, and crevasse splay. The existence, development, and spatial structure of a floodplain and its features are, in effect, a record of the past history of the river and its current activities. Floodplains have natural qualities that provide sites for agricultural production, urban expansion, industrial location, recreational activities, and conservation of nature and sites of cultural and historic value (see Nile and Mississippi photos).

Floodplain Development

Along the longitudinal river profile, tectonic interventions contribute to the formation of floodplains, creating different channel densities and patterns that influence hydraulic connections between lotic and lentic water bodies. Tectonic deformation of a river course leads to raised and subsided blocks displaying different hydrologic patterns (see A and B in Figure 2). Uplift blocks develop large and small lakes, whereas subsided blocks display complex anastomosing drainage patterns with a lot of irregular interconnected lakes.

Base level and climate changes to some extent influence floodplain development. The base level at the coast or valley mouth controls the upstream extent of horizontal and vertical channel migration, creating a landmass that can contain seasonal overbank flow and sediment deposition. Floodplain development is stabilized if there is a final standstill of the base level.

The scientists Wolman and Leopold proposed in 1957 a model of floodplain formation based

See also Sedimentation; Surface Water; Wastewater Management

Further Readings

The setting sun glints off the Amazon River and numerous lakes in its floodplain in this astronaut photograph from August 19, 2008.

Source: NASA.

Landsat 7 image showing floodplain of a section of the White Volta River in Ghana

Source: Author.
on geomorphologic reasoning and observation of streams. A floodplain is constructed entirely of horizontal layers of fine-grained sediments interrupted by coarse-grained channel deposit. It is dominated by braids and meanders migrating back and forth over the valley floor, leaving behind a sandy bar deposit.

According to Nevidimova, floodplains are formed due to the simultaneous horizontal and vertical displacement of the river channel. A displaced river in a horizontal plane leaves behind a low surface that gets inundated during high waters but changes with time.

**Types of Floodplains**

Geomorphologically, two types of floodplains can be distinguished, namely, hydrological floodplains and topographic floodplains (Figure 3). A hydrological floodplain is the land adjacent to the base flow channel residing below the bankfull elevation, which is inundated once every year. Not every stream has such a floodplain. A topographic floodplain is the land adjacent to the
Figure 2  A sketch showing different floodplain water networks in uplifted block (A) and sunken block (B) sectors nodal points (1 and 2)


Figure 3  Hydrologic and topographic floodplains. The hydrologic floodplain is defined by bankfull elevation. The topographic floodplain includes the hydrologic floodplain and other lands up to a defined elevation.

Floodplain deposits closest to the main channel are comparable with the main channel deposits but decrease in grain size with distance from the main channel.

Methods of Floodplain Delineation

Several methods have been developed to help delineate floodplains. These methods include remote sensing techniques and modeling within the GIS (geographic information system) platform using applicable algorithms. The hydraulic techniques use backwater modeling, based on losses along floodplain reaches. Backwater modeling uses hydrographs of complete events rather than the peak flow rate. Examples of the model include HEC-RAS, TELEMAC, SOBEK, and LISFLOOD-FP. Information required for these models includes the peak flow rate or event hydrograph (Figure 4), topography, and field data on channel and floodplain characteristics.

Uses of Floodplains

Floodplain resources provide a wide range of benefits to the surrounding communities. Communities use resources found on floodplains for the improvement of their livelihood, for example, firewood, tree stumps for shelter construction, and wood for fencing. Subsurface-water-level fluctuations of floodplains have potential effects on sustenance of stream flows, groundwater recharge, availability of water for livestock, and availability of water for dry-season irrigation. Floodplain use for crop cultivation during the season and off-season exposes the land to environmental hazards, altering its hydrodynamics and affecting the flora and fauna. The increasing use of agro-chemicals has the potential of polluting water bodies, changing the species composition, and entering the food chain. The human occupation of floodplains of major rivers such as the Nile, Mississippi, Ganges, Rhine, and Amazon has led to substantial impacts.

Figure 4  Event hydrograph of water height in a river for the period from August 29, 2005, to September 5, 2005

Source: Author.
Qualitative characterization of the observed cycle of land use activities on floodplains (Figure 5) and parameters such as the magnitude, frequency, areal extent, spatial distribution, and predictability of floods within a floodplain help avert land degradation to some extent.

Benjamin Kofi Nyarko

See also Coastal Erosion and Deposition; Floods; Rivers

Further Readings


Figure 5  Cycle of land use on floodplains of the White Volta River


Floods occur when streams and rivers overflow their banks and inundate the adjacent lands, called floodplains. In other instances, localized flooding occurs when drains cannot cope with heavy rainfall and along shorelines from sea surges that can be wind driven or associated with storms. Since all rivers flood and human activities frequently take place on the relatively flat floodplains, the consequences of flooding can be disastrous. Thus, the simple definition of flooding belies a complex of causal mechanisms that involve physical processes of the natural environment and social, economic, and political forces operating in the human environment. It is these factors in combination that determine the magnitude, severity, and ultimately the impacts of flooding. Thus, globally, floods are the most widely experienced natural disaster, causing property damage, economic disruption, and loss of life. At the same time, there are positive outcomes from flooding. Floods provide soil moisture for regions in which flood recession agriculture is practiced and can deposit nutrient-rich sediments to fertilize farmlands.
Causes of Floods

Floods can be understood within the concept of the drainage basin (watershed), often referred to as the fundamental unit of hydrological research. This unit can be viewed as a system, with one part inextricably linked to the next. The basic input to this system is precipitation, and it is how precipitation moves through various storage components that determines downstream discharge, the output to the system. The speed of water moving through the system and the associated “losses” to evaporation, transpiration, and storages in groundwater and lakes will affect the timing and quantity of water in the river channel. If the outcome is flows exceeding bankfull capacity, then there is a flood in that drainage basin (Figure 1).

Determining exactly how individual drainage basins respond to a given input of precipitation is a challenge to hydrologists. The characteristics of drainage basins, including their shape (especially at small scales), geology, soil types, vegetation, and geomorphology, all play a role in determining discharge. Furthermore, when precipitation occurs, it is the antecedent environmental conditions within the drainage basin that control flood severity. For example, snow cover, frozen ground, wet or saturated soils (or even dry soils on occasion), preexisting high river levels, ice-covered streams, and heavy precipitation can all exacerbate hydrological conditions and lead to floods. The response of a drainage basin to a given input of precipitation, therefore, may be relatively fast, or “flashy,” where flows can be high, peaking rapidly, often with a high velocity (Figure 2). In contrast, some systems may take days or weeks to reach peak discharge and inundate the floodplains, conditions that are termed sluggish. The former systems have a short precipitation-to-flood lag time, the latter, a longer lag time. So while all streams flood, they do not necessarily flood for the same reasons or in the same way.

The extensive flooding in the Midwestern United States in June 2008 demonstrates the role of antecedent conditions. These floods were triggered by a series of storms that crossed the

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**Figure 1** Stream cross-section and floodplain

region, dumping in excess of 12 in. (inches) of rainfall on top of already saturated soils following an abnormally wet winter and spring. The result was high streamflows and record-setting floods. Bangladesh, in contrast, regularly experiences flooding during the monsoon season, and consequently, local communities have adapted agricultural practices to these seasonal patterns. The floods of August 2007, however, were exceptional and caused widespread damage even though the total rainfall was somewhat less than normal. The floods occurred because most of the rain fell in just 2 months, June and July.

Under other conditions, severe storms have resulted in flash flooding as water moves rapidly through a drainage basin. For example, in mountainous areas, thunderstorms can concentrate water in narrow valleys, creating a wall of devastation as a flood wave cascades downstream. The Big Thompson, Colorado, flood of 1976, which killed 145 people, is a classic example. Similarly, arid regions can experience flash flooding. Heavy rainfall can exceed infiltration rates and lead to rapid surface runoff filling normally dry streambeds. One such event occurred in August 2008, when almost 4 in. of rain fell in 4 hours near the California-Arizona border, leading to flash floods that killed a number of people.

Shoreline environments add another dimension as coastal processes interact with the hydrological system to exacerbate flooding. In certain circumstances, low-pressure storm systems create a rise in sea level that can be increased further by wind action and high tides. It was just such events that led to the devastation of coastal communities by Hurricane Katrina. The geomorphology of shorelines can also influence flood severity. Bangladesh, for instance, is located where seawater is funneled into a narrow region by approaching storms, which increases sea levels. In addition, much of Bangladesh is situated on the floodplain at the mouth of the Brahmaputra River, so when rivers are high and storms approach, the result can be devastating.

**Flood Magnitude and Severity**

Determining the flood severity from a hydrological perspective is difficult; the metrics used focus on river discharge, water depth, velocity, and frequency. Discharge is measured by the volume of water passing a particular location over a given period of time, usually expressed in cubic meters per second (cms) or cubic feet per second (cfs). These values vary because they are related to the size and other characteristics of the stream and its drainage basin. For instance, the Big Thompson flood had a peak discharge of 883 cms (31,200 cfs), whereas the discharge of the Mississippi River at St. Louis in 1993 was in excess of 28,300 cms (1,000,000 cfs). By comparison, the average discharge on the Mississippi is approximately 16,000 cms (560,000 cfs). Therefore, comparisons of discharges among drainage basins are problematic because data are place specific.

Flood depths provide another metric of magnitude and present a better idea of potential damage than does the discharge. However, depth cannot be considered alone. It is the amount of water (depth) as well as how fast it is moving (velocity) that helps
explain impacts. Flood depths can usually be determined directly using stream gauges and indirectly by trash lines on structures left behind as water recedes. The velocity, on the other hand, has to be calculated from flow measurements along channels or through estimates of the speed of floating debris. Flow velocities in the Big Thompson flood were certainly faster than those in the Mississippi River floods. Hence, it is useful to differentiate between extensive and intensive events. Extensive floods, such as those associated with the Mississippi, can cover large tracts of land and usually allow time for warnings. The response time of the hydrological system to precipitation in these large drainage basins can be lengthy, with hydrographs exhibiting a sluggish time to peak discharge. Flood depths, however, can be considerable, exceeding 3 or 4 m (meters) on occasion. On the other hand, intensive floods, often associated with smaller streams such as those in the Colorado mountains or in smaller tributaries of the Mississippi, may not have great depths but frequently have high velocities that carry debris downstream with devastating impacts.

Flood frequency is another commonly studied component. Estimates of flood frequencies are based on records of flood events and average recurrence intervals. For example, a 100-yr. (year) flood refers to the discharge for a specific drainage basin that is expected to be equaled or exceeded once every 100 yrs. A flood of this magnitude has a 0.01 probability (1% chance) of occurrence in any given year. The greater the discharge, the less chance there is of its occurring because of the extreme conditions required for large-magnitude events. Thus, a 500-yr. flood has an annual probability of occurrence of only 0.002. Unfortunately, this terminology is often misunderstood or poorly perceived. Too often, once a community experiences a 100-yr. flood, residents believe that they are now completely safe, at least in their own lifetimes. In fact, several 100-yr. floods can occur in the same year. Nevertheless, this method of estimating floods is useful for designing flood mitigation structures and for developing land management plans for specific-size events. Because the spatial extent of inundation can be estimated, it provides a guide to flood-prone lands within drainage basins.

Coastal flooding is usually measured in terms of storm surge height, although velocities, set up by strong winds, can make a significant difference. Water surge elevations in the absence of wind and waves are used to project the 1% event. Although storm surge varied with Hurricane Ike in Texas, in some areas a 5-m storm surge was capped with battering waves, leading to the destruction of entire neighborhoods. Hence, as with riverine floods, depth and velocity work together to help determine destruction potential.

Human intervention in drainage basins can have an important impact on the size, lag time, and frequency of flooding. Activities such as developing land for urban uses, using tile drainage to increase the productivity of agricultural lands, and straightening and channelizing rivers alter natural processes, changing the quantity and velocity of floodwaters and often making the system flashier. Other practices such as constructing storm retention ponds and creating wetlands can have the opposite effect and prolong lag times and thus reduce the impacts of flooding.

### Flood Mitigation

While floods can have positive impacts, they are mostly associated with property damage and loss of life, particularly because of our propensity to live near rivers and along coasts. Not surprisingly, then, various approaches have evolved for mitigating these adverse impacts. Such adjustments can generally be divided into structural and nonstructural measures, which operate individually or in combination to minimize losses due to these events.

Structural measures are designed to protect against flooding by separating human activities from floodwater. Through engineering works such as dams, levees, flood walls, and seawalls, floodwater can be stored in reservoirs or confined to channels, at least up to the design levels (standards) of the structures. The discharge for which these mechanisms are designed depends on the drainage basin’s flood history, physical characteristics, and social, economic, and political factors. While it is technically possible to protect against a flood with a recurrence interval of, say, 500 yrs. (0.2% chance of occurrence), the cost of such protection frequently outweighs the benefits, measured in flood losses avoided. So flood control structures tend to be designed to protect against floods with recurrence intervals of up to approximately 200 yrs., with local variations.
Flood control structures have been quite successful as a mitigation strategy and have prevented billions of dollars in damage. Nevertheless, some problems have arisen. First, structural design standards may be exceeded, which can lead to catastrophic failures as when dams collapse or levees break, triggering high-velocity floods that completely destroy communities. Flood control works also invariably induce a false sense of security wherein risk is perceived as minimal and design limitations of engineering projects are ignored. Consequently, development continues in risky areas, greatly increasing the exposure of property and lives, because the community is now perceived as protected. When structures fail or when design standards are exceeded, damage can be substantial. A further complication is the changing nature of flooding, whether from global climate change or land use modifications that alter hydrological processes within drainage basins. Flood frequencies and magnitudes may adjust and compromise the effectiveness of structures.

Mitigation through nonstructural measures includes land use zoning, building codes, insurance, and warning systems, among others. Keeping floodplains undeveloped or in low-density uses that are not as likely to incur significant losses is one approach. If construction is permitted, then flood-proofing buildings by elevating them on stilts or fills or temporarily sealing entranceways will reduce damage. In some drainage basins, forecasting and warning systems can mitigate losses by providing time for remedial action, such as protecting property from flooding, and for evacuation. Many nonstructural measures are relatively low cost when compared with flood control structures and can be effective in reducing losses by reducing exposure. However, there are numerous social, economic, and political factors that complicate such practices. For instance, geographical inertia invariably works against relocating residential, commercial, or industrial buildings already located on a floodplain. However, relocation is an option. Valmeyer, Illinois, for example, moved off the floodplain following the 1993 Mississippi River floods, and portions of residential neighborhoods of Conklin, New York, were turned into natural areas following a repeated flooding on the Susquehanna River from 2004 through 2006. Rather than relocating communities, some buildings can be flood-proofed to keep water out or to let it pass below an elevated structure. However, this may not be cost-effective for some buildings. Also, many nonstructural measures require positive action on the part of floodplain dwellers; they must purchase flood insurance policies or respond appropriately to flood warnings. Unfortunately, promoting such behavioral change is not easy.

**Conclusion**

Floods are natural physical processes that provide benefits to the surrounding floodplains. The physical and hydrological processes that generate floods are rather well understood, though much remains to be learned about the interaction of atmospheric and hydrological systems. However, when the human environment intersects with these natural processes, disastrous outcomes can result. Flooding is a global concern: It affects communities around the world and normally leads to more death and damage than do all other natural hazards in any given year. Thus, a comprehensive understanding of floods requires incorporation of the social, economic, and political forces that lead to the use of floodplains and coastal areas, in addition to hydrological and atmospheric modeling to determine drainage basin form and process.

_Burrell Montz and Graham A. Tobin_

See also Environmental Perception; Flash Floods; Floodplains; Flow; Natural Hazards and Risk Analysis; Surface Water

**Further Readings**

- Association of State Floodplain Managers: www.floods.org/home
- NOAAWatch—Floods monitor: www.noaawatch.gov/floods.php
- USGS—Natural hazards – floods: www.usgs.gov/hazards/floods
Flows are a term used to describe fluids in motion. Air and water, fluids ubiquitous in our environment, are of great interest to geographers. Air and water behave in similar ways; the main difference between these respective fluids is their density. Water is close to 1,000 times denser than air. The manner in which flow occurs and the resulting behavior of fluids can be subdivided into two categories, turbulent flow and laminar flow. Both the density and the viscosity of the fluid play an important role in determining which form of flow will occur.

Laminar flow is sometimes referred to as streamline flow. This type of flow refers to fluids moving in parallel layers, with no disruption or mixing between the layers. Such a lack of interactions between the fluid layers elucidates the fact that no eddies or irregular interactions occur in laminar flow conditions. When a flow is either extremely slow or close to a surface boundary, such as a streambed, laminar flow can occur in lower-viscosity fluids. Higher-viscosity flows, such as lava flows, are also likely to be laminar.

Turbulent flows occur in the vast majority of natural streams and are the most commonly encountered flow state. In such waterways, eddies are continuously forming and dissipating. Turbulent flows indicate flows that on an individual-particle level appear to be chaotic or stochastic, with the formation of large-scale eddies being characteristic. Individual water molecules in a turbulent regime follow apparently haphazard pathways that can take each molecule in alternative directions to the overall downstream direction. However, the general downstream flow direction is maintained and is the dominant flow direction superimposed on the random motion of individual molecules.

Rising smoke from a lit cigarette can help us visualize the difference between laminar and turbulent flow. As the smoke exits the cigarette, it rises vertically, in a laminar fashion. However, as the smoke continues to spiral upward, it begins to dissipate and interact with the surrounding air, and turbulent eddies become visible.

The Reynolds number (Re) is a dimensionless parameter that can be used to characterize different flow regimes. Laminar flows occur at low Reynolds numbers (<2,000), where viscous forces are dominant and smooth fluid motion exists, while fully developed turbulent flows occur at high Reynolds numbers (>4,000). A transitional zone exists between Re values of 2,000 and 4,000. Here the flow can be either laminar or turbulent, depending on a number of factors, including the roughness of the surface that the flow is in contact with. The Re value at which the flow becomes turbulent is referred to as the critical Reynolds number.

Sarah McCormack

See also Groundwater; Rivers; Surface Water; Wastewater Management

Flow Maps

Flow maps depict the movement of phenomena between geographic locations, typically using lines of varying widths to depict quantitative data, although different color hues, in the case of qualitative data, may also be used. In the older literature, flow maps are also referred to as dynamic maps. In directed-flow maps, the flow travels along the line only in the direction of the arrowhead. In contrast, in undirected-flow maps, arrows are missing, and movement is possible in both directions.

Flow maps can be categorized into the following five types: distributive, network, radial, continuous, and telecommunications. A distributive flow map depicts the movement of commodities, people, or ideas between geographic regions. Flows within a network, such as the transportation network, are depicted in network flow maps. Radial flow maps possess a distinctive radial or spokelike pattern. Good examples are a street network based on traffic circles and an airline route network based on the airport hub structure. The movement of continuous phenomena, such as wind or ocean currents, is best shown with continuous flow maps, while the flows of information technology, including the Internet, are depicted in telecommunications flow maps.

The earliest flow map dates to 1837 and was created by Henry Drury Harness. Minard of France not only popularized the flow map among statisticians (Figure 1A) but also became known for the flow chart showing the demise of Napoleon’s army in Russia. In the early decades of the 20th century, flow mapping became common in
geography textbooks with the impetus supplied by the study of economic geography. Among the first to develop an automatic solution for displaying migration flows was Waldo Tobler, with his Flow Mapper software (Figure 1B). Details about the software, including a free download option, can be found at www.csiss.org/clearinghouse/FlowMapper. A more recent example of a flow-mapping software was developed by Doantam Phan and his colleagues from Stanford University (Figure 1C). Details about their software, including a free download option, can be found at http://graphics.stanford.edu/papers/flow_map_layout.

Recently, Ningchuan Xiao and Yongwan Chun developed the kriskogram, which is a new method to visualize migration flows. In a kriskogram, geographical units are projected as a set of points on a straight line segment called a location line. The migration flow between two points on the location line is represented using a half-circle drawn from the origin to the destination in a clockwise direction (Figure 2, next page).

Michael Leitner

See also Cartography; Choropleth Maps; Isopleth Maps; Map Design; Map Visualization
A geologic fold occurs when a flat surface is bent or contorted. For a rock or sediment to show its folds, it must have a set of parallel surfaces or different layers inside it. A very homogeneous rock mass with no internal variation would not show that any force had been applied to it to make it fold. Folds form in sediments and rocks generally from near the surface to as much as 45 km (kilometers) deep in the Earth, where elevated temperatures and the high rock overburden and fluid pressures cause the rocks to be ductile and change shape as they are subjected to tectonic or other forces from glaciers and surface processes. This allows their development in sediments and sedimentary rocks, in a full spectrum of metamorphic

**Further Readings**


**Figure 2**  Kriskogram of interstate migration in the conterminous United States


Note: The states are arranged according to the longitude of their centroids. Migration flows with magnitude smaller than 77,059 are treated as background and are not shown.
rocks, and even as primary flow structures in some igneous rocks. Folds can even occur in soft sediments, where varied conditions of confining stress, hydrostatic pressure, and pore pressure allow their development. Folds in rocks occur at scales ranging from the microscopic to vast regions best observed by satellites in space. Folds distributed on a regional scale constitute a fold belt, which is a common feature of orogeny or mountain-building zones. Folds can also range from aesthetically pleasing, simple waveforms all the way to vital traps for hydrocarbon accumulation; their great variety has excited the curiosity of lay people as well as the geologists and geophysicists who study them intensively. Three main approaches have been used to study folds:

1. The study of the geometry and internal structure of natural folds
2. Theoretical analysis of folding processes
3. The formation of experimental folds in the laboratory

In the course of the study of folds, an extensive and sometimes confusing descriptive terminology of form has been developed to classify them by their size and shape, or geometry and morphology, the tightness of the fold, and the dip of the axial plane, as well as by their mechanics of growth, kinematics, and tectonic frameworks. The first consideration is fold description and classification. The region of maximum curvature of a fold is the hinge zone or fold nose, where the limbs of the fold close. The axial surface of a fold connects the hinge zones of the various folded layers, and an axial line connects the points of maximum curvature in any one bedding surface of a fold. Folds that close upward are antiforms, and those closing downward are synforms. Sedimentary rocks have a variety of structures that show superposition or the right way up (younging direction). If an antiform has its younging direction upward, it can be considered an anticline, whereas a synform with the same superposition direction is a syncline. Folds face in the direction of the stratigraphically younger rocks; vergence is the direction in which structures face. If sedimentary rocks are overturned from their original superposition, established when they were deposited, it is then possible to have synformal anticlines and antiformal synclines. The plunge inclination is the attitude of the axial line relative to a horizontal plane.

Many different kinds of folds have been recognized over the years, so that a symmetrical fold is one in which the axial surface is everywhere equidistant from the limbs of the fold, whereas an asymmetrical fold is one in which the axial surface is not equidistant from the limbs, which commonly dip different amounts. An upright fold has a vertical axial surface, whereas an inclined fold does not. Fold tightness is the angle between the limbs of a fold. Gentle folds have an interlimb angle of 170° to 180°; open folds, 170° to 90°; and tight folds, 90° to 10°. Isoclinal folds have an interlimb angle of 10° to 0°, with essentially parallel limbs. An overturned fold has one limb that has passed the vertical so that its bedding is upside down from its original superposition order. A recumbent fold is so overturned that its axial surface is essentially horizontal. Fold nappes are those huge recumbent folds that extend for many tens of kilometers in orogenic areas such as the Alps. A monocline is a local steepening of dip in an area of otherwise flat-lying rocks, whereas a structural bench is a local flattening in otherwise dipping rocks. A doubly plunging anticline is warped down at both ends, whereas a structural dome has rocks that dip down on all sides from a central point. A structural basin has rocks that dip upward on all sides from a single point. Folds that maintain uniform layer thickness are classed as parallel, competent, or concentric folds. Similar folds have thinning of the limbs and thickening of the hinge zone. Parallel folds are caused by warping that results from deformation of the layers themselves, whereas similar folds usually form by some form of dislocation or flexural sliding between the layers, with extension or thinning in the fold limbs and thickening of rock layers in the hinge zones. Folds can be shaped in various ways, as chevron folds, with planar limbs meeting at an angular axis, as cuspatte with curved limbs, as circular with a curved axis, or as elliptical with an unequal wavelength. Ptygmatic folds are formed in high-grade metamorphic rocks and are chaotic, random, or disconnected. Some may have been planar originally, whereas others may have been injected as igneous veins under special circumstances. They
are typical of folding in sedimentary slumps, half-melted migmatites, and decollement detachment zones.

The folding of layered rock is caused when compressional force causes them to buckle, bend, or fold passively. Buckling of rocks occurs when the force is applied parallel to rock layers that are of different strengths. The layers slip past each other as the fold propagates to larger and larger amplitudes. Bending folds occur when the force is perpendicular to the rock layers. This can happen when another mobile material such as rock salt pushes up into overlying rocks and bends them into a dome. In addition, when forces produce fault breaks in the rock, folds can result when the shear surfaces are not planar and change direction. In passive folding, the layering has no mechanical significance, the forces on the rock may be oblique, and the rock records the deformation by changing shape internally and externally.

John F. Shroder

See also Faulting; Geomorphology; Sedimentary Rock

Further Readings


FOLK CULTURE AND GEOGRAPHY

Folk culture refers to traditional, often rural, cultural production in the form of symbolic practices and cultural artifacts. In geography it is a concept, traditionally linked to the Berkeley School of cultural geography and Carl Sauer, which fell into disfavor with the rise of critical cultural geography in the 1980s. However, geographers have more recently recovered the concept in the analysis of national identity and commodification of culture and given it a more dynamic meaning.

Prior to the rise of the new cultural geography in the 1980s, cultural geography was focused on rural life and particularly the distribution of cultural artifacts over space. For example, a cultural region could be defined by the style of vernacular or folk architecture found in an area. Geographers located cultural hearth areas and traced the diffusion of particular barn, house, or church styles. This work was based on a relatively static understanding of culture as a coherent “way of life” that changed slowly and could be attached to a particular territory. Urban culture was seen as corrupted and was generally not an object of study. Instead, geographers sought the authentic culture of small isolated groups. With the rise of the new cultural geography under the influence of Raymond Williams and Stuart Hall, geography’s understanding of culture became more sophisticated, and geographers particularly became concerned with culture as a site of struggle. Traditional studies of folk culture fell out of fashion, and geographers concerned with culture focused more on popular culture. However, geographers still found ways to examine folk culture from a critical perspective.

In some ways, popular culture is everything folk culture is not. Popular culture tends to be urban and industrial in nature. There is an explicit recognition of hybridity and change in the study of popular culture. Popular culture is made up of the meanings people create in conversation with mass-mediated, mass-produced, commodified culture. But the distinction between folk and popular culture is not clear-cut. Rural cultures and oral traditions can no longer be seen in isolation from one another and from the world of commodity production. In anthropology, where folk culture and folklore studies are more central than in geography, researchers have moved folklore out of the realm of the static and the rural and begun to concern themselves with the grassroots, oral side of modern life, studying the exchange of folklore via the Internet, for example.
The European concern with folk culture goes back to the work of the German philosopher Johann Gottfried von Herder in the late 18th century, and the study of folklore became an important element in the creation of nation-states in the 19th century. Folklorists sought to define national cultures and link them to particular territories by going out into the countryside and collecting examples of authentic folk culture. They collected stories, songs, music, dances, and costumes and selectively interpreted their findings to argue for timeless, essentialist national cultures attached to particular territories, thereby legitimizing territory-based nation-states. Critical human geographers have analyzed this process of nation building.

Allan Pred coined the term *folk geography* to describe working-class practices of spatial orientation in late-19th-century Stockholm. At a time when modernity swept through Stockholm and the city went through an unprecedented period of sociospatial transformation, the newly emerging working classes developed a folk geography that made the constantly changing city a familiar

Chinese babies and children are hoisted during the Beizhuang performance in Songxian county in China’s Henan Province on February 11, 2006. Beizhuang is a folk art form popular among the people of Zhenxidian Village. Passed down from generation to generation, Beizhuang has developed into a complex performance featuring many aspects of the folk culture of Central China.

Source: AP Photo/EyePress.
and preserved memory and resisted the official, ideologically loaded street names imposed by the nationalistic bourgeoisie. Members of the new urban working class practiced oral recalcitrance in stubbornly refusing to utter new names and in continuing to use intergenerationally sedimented place names that referred to the everyday use or history of a place. Pred uses the term folk geography interchangeably with popular geography, which reflects the ambiguous distinction between folk and popular culture. On the one hand, the urban working classes in late-19th-century Stockholm were recent migrants with one foot in the countryside. Their naming practices were full of the folk humor and sensibilities of village and rural life. On the other hand, they were an industrial proletariat living in a modern cosmopolitan city, and they developed their language of spatial orientation in response to these conditions. Pred is particularly able to conceptionalize folk culture as a dynamic practice deployed in the struggles of modern urban life, in contrast to the older, more static conceptions of folk culture.

James Freeman

See also Architecture and Geography; Berkeley School; Cultural Geography; Popular Culture, Geography and; Pred, Allan; Sauer, Carl

Food, Geography of

Everyone needs to eat. This basic fact of life is complicated by the rich variety of social meanings and environmental practices associated with food. The result is a complex, almost bewildering, geography of food. Shelves at modern grocery stores around the world are stocked with a vast range of foods, including many exotic foods that were out of reach for most consumers less than a generation ago. At the same time, hunger haunts almost 1 billion people, mostly, but not exclusively, in the global South, while small and subsistence farmers find it harder to sustain their livelihoods amid intense international market competition. Food has been an important object of economic, political, and scientific calculation and manipulation in the long-term development of globalization, as well as the foundation for social movements based on the defense of locality, nature, and culture. Understanding food’s multifaceted place thus requires a geographic approach that can make sense of the complexity of food in its social and environmental contexts.

Agriculture, the planned cultivation of plants and animals for human consumption, is one of humanity’s oldest markers of “civilization.” It has long been the focus of new technological developments that alter the physical environment to suit human needs and has been the necessary obverse of urbanization, which facilitates the storage, trade, processing, and control of food. Geographies of food are therefore geographies of power, and the study of agricultural production in particular was of primary concern in modern geography prior to World War II. Early geographic theories and models, such as the von Thünen model, and descriptive studies of regions, all included some mention of food production and distribution, though often in narrowly economic terms. In the post–World War II period, and especially in relation to concerns with and research on population growth, environmental degradation, and development in former colonies, the study of the geography of food became increasingly interdisciplinary and, in many respects, highly technologized, as did modern agriculture itself.

Social scientists and technical specialists, including geographers, paid special attention to
agriculture’s role in the development process in the decades following World War II, aiming to increase yields and efficiency through mechanization and green revolution technologies, such as new hybrid crop varieties. This shift produced more food, as the general lack of food in the developing world was understood as one of the main impediments to successful development. A more technologically and economically sophisticated farm sector would mean more food, more urbanization, and greater political, social, and economic stability. Peasant and subsistence food systems were deemed inadequate to meet the needs of developing societies, and the geography of food was remade to fit the models of development experts and the political mandates of Cold War geopolitics. While aggregate measures of food production and food security showed progress, rural dislocation, widespread environmental change, and irreversible changes in cultural practices indicated that the geography of food was more complex than net increases in agricultural production alone could describe.

In the developed world, including communist states under the Soviet umbrella, the postwar geography of food became increasingly reliant on technological innovation as well, with industrialized food production requiring massive chemical inputs to keep pace with the increasing demand. By the 1980s, and especially in the 1990s, the technological revolution in food production shifted to the molecular level with breakthroughs in genetic engineering and biotechnology, while at the global scale, the Cold War’s end produced an economic environment in which food became central to world trade and its liberalization. These were not unconnected developments, as the international trade regime instituted in the General
Agreement on Trade and Tariffs and, after 1995, the World Trade Organization (WTO), made food subject to the pressures of neoliberal globalization, centered on free trade and dominated by the interests of international investment. Many developing states reversed policies of subsidies for small farmers and food self-sufficiency in favor of increased specialization in production for export and reliance on international markets to meet national food needs. Meanwhile, states in the global North often failed to meet their own WTO obligations to cut agricultural subsidies while investing in further biotechnology research, introducing new genetically modified foods to markets and sparking a contentious debate over globalization’s impacts and direction.

While such shifts mean that it is now possible to shop at a Tesco supermarket in Malaysia, enjoy imported mangoes in the convenience of a Chicago home, or eat at McDonald’s almost anywhere in the world, understanding the spectacular explosion of global food connections must not neglect the localized and contested networks of people, places, and processes that are the other side of globalization. Numerous food-based challenges to the neoliberal version of globalization have arisen, including consumer advocacy groups in the global North concerned with food safety, organic and “slow-food” movements centered on industrialized food’s detrimental ecological and health effects, and calls for “food sovereignty” and localization from farmers’ movements around the world, wherein consumers seek to purchase food grown nearby, thus saving transport costs and energy inputs. These critiques and alternatives reassert the importance of the personal, local, and regional scales in our social relationship to food and rely on claims about the centrality of public and ecological health, rather than profit maximization and investor rights, for regulating food.

Geographers examining food today have a wealth of information and examples with which to work. Attempts to reconcile, or even overturn, narrowly economic perspectives on food with theoretical approaches that recognize the vital cultural, social, and political roles of food in daily life have also produced overt challenges to the geography of food underwritten by the institutions of neoliberal globalization. The future of food remains open to debate, but a food system that can ensure social justice, ecological sustainability, and human security requires taking seriously all aspects of the geography of food and working to understand the ways in which food, place, and society are intertwined.

Jamey Essex

See also Agricultural Biotechnology; Agriculture, Industrialized; Agriculture, Preindustrial; Agroecology; Agrofoods; Aquaculture; Consumption, Geographies of; Famine, Geography of; Fish Farming; Food and Agriculture Organization (FAO); Hunger

Further Readings


The United Nations’ (UN) Food and Agriculture Organization (FAO) is the international organization responsible for improving food security and forest management through the collective efforts of its member states. For geographers it is an important source of international land use statistics.

History and Constitution

The FAO was founded in 1945 at the first session of the FAO Conference, held in Quebec City, Canada. Its Forestry and Forest Products Division was established in 1946. The conference is FAO’s supreme governing body, and all member states, which currently number 191, attend its biennial meetings. It elects FAO’s director-general, who manages the secretariat, and the
FOOD AND AGRICULTURE ORGANIZATION (FAO)

council, a body of 49 member states that meets at least four times between conference sessions and is FAO’s executive organ.

FAO’s activities are undertaken by the Departments of Agriculture and Consumer Protection, Fisheries and Aquaculture, Forestry, Economic and Social Development, Natural Resources Management and Environment, and Technical Cooperation. The first three departments have their own supervisory committees on which member states are represented.

FAO’s staff of 3,600 people are deployed in its headquarters office in Rome, 5 regional offices, 9 subregional offices, 5 liaison offices, and 74 country offices.

Status Within the United Nations System

The FAO is a specialized agency of the UN. As with similar bodies, such as the UN Educational, Scientific and Cultural Organization (UNESCO), it reports to its own member states, not to a UN central organ such as the General Assembly or the Economic and Social Council. In contrast, programs of the UN, such as the UN Development Programme and UN Environment Programme, do report to central organs and receive their budgets from central funds. The World Food Programme, whose mandate is to respond to food emergencies, is jointly responsible to the UN General Assembly and the FAO but is based at FAO headquarters.

Role Within the Forestry Profession

The FAO’s Department of Forestry provides a global nexus for the reproduction of the common institutions of professional foresters, taking over a role previously exercised by European colonial forest services. Many foresters still work for governments, and at any time a significant proportion of the FAO’s staff are seconded by member states. The FAO publishes the journal Unasylva and every 6 yrs. (years) convenes the World Forestry Congress, one of the largest international gatherings of foresters.

FAO Statistics on Forests and Land Use

FAO publishes various types of international statistics. Three are particularly relevant to geographers:

1. Statistics on world trade in forest products are published annually in the FAO Forest Products Yearbook by the FAO Department of Forestry.

2. Statistics on land use are published annually in the FAO Production Yearbook by the Statistics Division of the FAO Department of Economic and Social Development. These include data under the following headings: Arable Land, Permanent Crops (e.g., tree crops), Permanent Meadows and Pastures, Other Land, and, until 1995, Forests and Woodlands.

3. Statistics on global forest resources were published in the World Forest Inventory series between 1948 and 1963 by the FAO.

Studies of FAO

Organizations within the UN system come under the more general heading of “international organizations” (IOs). These are generally understood in the international relations literature to be sustained groupings of states, convened for a common purpose and operating according to an agreed set of rules or institutions. In the neoliberal theory of international relations, such institutions help reduce the instability caused by the self-interested decisions of states.

The day-to-day operations of an IO are carried out by a secretariat. Few academic analyses of these have been undertaken, and many of them deal with the World Bank. Studies of IOs have focused on those that maintain peace and security, thereby giving prominence to member states rather than to secretariats. Yet in specialized agencies such as the FAO, which are mainly concerned with technical, not political, matters, the role of the secretariat assumes great importance. Sadly, most IOs do not facilitate external studies, perhaps because they equate critical academic evaluation with negative “criticism.”

Two key research questions currently being addressed in this field are the subject of recent books. First, how autonomous are IOs in relation to their member states? Second, how autonomous are the bureaucratic secretariats of IOs?
Department of Forestry and the joint Agriculture and Timber Division of the UN Economic Commission for Europe (ECE) and FAO in Geneva, Switzerland. Statistics on temperate forest resources were then published periodically by ECE/FAO. In 1981, the FAO Department of Forestry produced an encyclopedic Tropical Forest Resources Assessment 1980, which was followed in 1993 by Forest Resources Assessment 1990 (Tropical Countries). In 1995, global coverage was resumed with the publication of Forest Resources Assessment 1990: Global Synthesis, which included temperate forest statistics from ECE/FAO. Global Forest Resources Assessment 2000 was the first to apply uniform definitions to all forests.

The Use of FAO Statistics in Geographical Studies

Statistics on tropical forest areas and deforestation rates in FAO’s Forest Resources Assessments (FRAs) have been used in 159 academic studies. Of these, 47 involved constructing cross-sectional regression models to make international generalizations about the factors causing and controlling deforestation, 33 entailed monitoring or forecasting trends in carbon stocks and emissions in relation to global climate change, and 18 involved monitoring or forecasting trends in biodiversity. The remainder were generally descriptive in content.

Few of these studies evaluated the quality of the FRA data they used. Regression studies that identified population growth as a significant variable driving deforestation were unreliable because many FRA estimates relied on models including population growth rates. There are numerous inconsistencies among statistics in successive FRAs, for example, between estimates of forest areas and overall trends in forest areas. These stemmed from difficulties in combining large numbers of national statistics in a coherent way. Annual Forests and Woodlands statistics in FAO Production Yearbooks have been used in some deforestation studies. But as these statistics are only those reported each year by governments, not measured each year, their quality is not very high.

Alan Grainger

Further Readings


Footprint Analysis

See Ecological Footprint

Fordism

The term Fordism was originally invoked by early-20th-century trade union activists to describe the
brutal system of machine-paced production methods deployed in automobile plants owned by Henry Ford. Ford’s method radically transformed the conditions and rhythm of work on the shop floor. In the 1930s, Fordism was used by the Italian Marxist political theorist Antonio Gramsci to denote the peculiarly American form of modern production prefiguring a new stage of industrial capitalism. For late-20th-century social theorists, the system of production at Ford Motor Company in Michigan, first at the Highland Park plant in the 1910s and then at the massive River Rouge factory beginning in the late 1920s, was often used as the exemplary case of classic Fordism.

A hallmark of classic Fordist production is that large numbers of semiskilled and unskilled workers perform routine standardized tasks arranged sequentially to facilitate the steady and rapid flow of materials from one station to the next. In the Fordist system of mass production, the high volume of output allows the company to spread the cost of expensive, single-purpose capital equipment over a large number of outputs, thereby exploiting economies of scale in the production of consumer goods. This production process contrasted with the small-batch method, in which skilled craft workers would use mostly hand tools to fabricate parts and assemble the product in discrete stages. Machine pacing allowed managers to “speed up” the production process by increasing the pace at which the conveyor moved work through the plant. One of the key characteristics of classic Fordism is the extensive use of mass production techniques that shift control over the pace of work from craft workers to machines and managers. As such, Fordism has come to be seen as the antithesis of craft-based, multiskilled, team-supervised production processes.

Mass production facilities were not only labor intensive, they were land intensive as well. So the central city was no longer a viable site for manufacturing because it could not accommodate the spatial requirements of mass production. The mass production factory layout required a horizontal floor plan to promote the efficient movement of parts and subassembly processes. This technological factor compelled firms to locate outside the central city. In addition, resistance to unionization and fear of spreading strike activity motivated owners to begin to spatially isolate their massive production facilities. In the auto industry of the late 20th century, a similar set of considerations underlie the construction of “greenfield” facilities by Toyota, Honda, and BMW in Alabama, Southern Ohio, and South Carolina.

The spatial logic of Fordist production relied on the dual requirements of ready access to unskilled and semiskilled labor and relatively inexpensive land. For example, the River Rouge plant, built in the Detroit suburb of Dearborn, was a sprawling facility that internalized the chain of commodity production by fabricating parts on site. In addition, Ford owned copper mines in the Upper Peninsula of Michigan and a rubber plantation in Brazil. So another signal feature of Fordist production is centralized production and direct control of resources. However, the situation at Ford Motor was more complicated than this. At the same time when the Rouge plant was in operation, Ford experimented with the production of decentralized parts under varying technological and social conditions ranging from highly skilled unsupervised work teams to unskilled small-scale versions of mass production and hybrid operations combining aspects of mass production with craft practices. This strategy suggests that classic Fordism was at best partial and incomplete even at Ford Motor and implies that the concept of Fordism serves as an ideal type.

In the early to mid 20th century, the basic characteristics of classic Fordist mass production quickly became synonymous with modernity, rationality, and efficiency. Fordist practices were studied and applied to manufacturing in the non-capitalist countries of Eastern Europe. Fordist principles and aesthetics captivated modern 20th-century architects, notably Le Corbusier. Single-family housing, manufactured using mass production techniques by developers such as Abraham Levitt in Long Island, New York, provided an affordable option to working-class families, allowed suburbanization, and encouraged patterns of spatial segregation by race and class.

The viability of Fordist production depends on the successful synchronicity of mass production with mass consumption. Wages need to be high enough to generate sufficient sales of mass-produced consumer goods. Ford’s $5 per day, introduced in 1914, was a significant increase in wages and is emblematic of this strategy, although
the rationale for the $5 day involved reducing costly worker turnover and forestalling the threat of unionization as much as providing workers with a new consumption standard. Union wage demands became defined in terms of the ability of workers to afford mass-produced consumer goods throughout the early and mid 20th century. In addition, the Keynesian welfare state was charged with sustaining consumption in the face of declining employment and stagnant real wages. According to “regulation theory,” the creation of a national political economy premised on mass production, mass consumption, collective bargaining, and a government income support policy characterized the Fordist regimes established in Western Europe, Australia, the United States, and Canada after World War II.

Proponents of post-Fordism or flexible specialization maintain that in light of the breakdown of mass production and unraveling of the Keynesian coalition in the 1970s, new systems of production began to take hold. These alternatives to mass production required access to highly skilled workers able to perform a variety of tasks, participate in team production, and maintain flexible work schedules. This theory assumes a schism between

Workers are photographed on a flywheel assembly line at the Ford Motor Company’s Highland Park, Michigan, plant in 1913. The use of a moving line reduced a car’s assembly time from 12 hours to 93 minutes.

Source: AP Photo/Ford Motor Company.
FOREIGN AID

Fordism and its other (post-Fordism, flexible specialization) that elides any interdependencies between the two forms of production. Instead, mass production and small-batch production, unskilled work and skilled labor, horizontal integration and outsourcing of production are all elements of capitalist production reflecting temporal variations in both the spatial flows of capital and shifts within a global division of labor. Indeed, within contemporary transnational networks of production dominated by neoliberal economic policies, intranational Fordism is being displaced by a global system in which Fordist mass production facilities, located within largely developmental and transitional nation-states, supply consumer markets in core capitalist countries.

Bruce Pietrykowski

See also Automobile Industry; Economic Geography; Flexible Production; Industrialization; Labor, Geography of; Regulation Theory

Further Readings


FOREIGN AID

Broadly speaking, foreign aid implies a transfer of resources from one country, referred to as the donor, for the benefit of another, called the recipient. This transfer can take place directly, through bilateral channels, or indirectly, through multilateral ones. The purpose of aid varies over space and time, ranging from military aid to humanitarian. In more strict definitions, the concept refers exclusively to official development aid, which should be distinguished from humanitarian or relief aid. The former aims at finding long-term solutions that allow recipient societies to meet and generate solutions to their needs, the latter at alleviating human suffering in urgent situations. Flows of resources aiming at generating development are of three types: (1) official development assistance (ODA), (2) foreign direct investment (FDI), and (3) private donations. According to the Organisation for Economic Co-operation and Development (OECD), ODA includes grants or loans to developing countries that are (a) undertaken by the official sector, (b) with promotion of economic development and welfare as the main objective, and (c) at concessional financial terms (if a loan, have a grant element of at least 25%). Grants, loans, and credits for military purposes are generally not included, but it was exactly in this field that the history of aid began. Today, the relevance of foreign aid lies in the fact that it is one of the most important means used to assist the developing world in achieving poverty reduction and economic and social advance.

History

In Western history, the origins of foreign aid can be traced back to when states supported militarily strategic partners, but it is not until the 18th century that foreign aid became more systematic. The best examples are, perhaps, the use of British foreign aid in its rivalry with France or the subsidies of Prussia to some of its allies. The 19th century witnessed the first steps toward foreign aid as we know it today. In 1812, the U.S. Congress passed the Act for the Relief of the Citizens of Venezuela. In the 1870s, the first discussions on the finances for the colonies took place in Britain,
leading gradually to Britain’s passage of the Colonial Development Act in 1929, which provided modest government funds to facilitate development in the colonies rather than forcing them to rely on exports of agricultural goods. However, many of the ideas and infrastructure that sustain present foreign aid were born in the post-war period. The Bretton Woods Conference in 1944, the establishment of the United Nations in 1945, the launching of the Marshall Plan in 1947, the creation of the UN Technical Assistance in 1949, and the Development Assistance Committee (DAC) of the OECD in 1961 mark some of the grounds of modern foreign aid. The scale of foreign aid grew bigger with the independence of nation-states in the developing world.

Since its start, modern foreign aid has shifted strategies. The driving forces that lie behind this are to be found in the relationship between foreign aid and development doctrines. Thus, during the 1950s, when belief in industrialization prevailed, foreign aid focused on aggregate large-scale resource transfer to trigger or speed up the Rostovian industrial “take-off.” In the late 1960s, economic dualism between the innovative export sector and a traditional, locally oriented one, as well as human-capital issues such as education and technical training, became relevant to development theories, making foreign aid incorporate more issues such as education and rural development. A further shift took place during the mid 1970s, when development theories began pointing at serious hindrances to economic development related to rural-urban migration, unemployment, and mass poverty. In the 1980s, the deep economic stagnation in Africa and the inability of different political regimes to overcome it were hard to ignore. In this state of things, the successful East Asian economies attracted attention and became the central model in development debates. Based on specific interpretations of this success, foreign aid became more conditional and focused on structural adjustment programs that were supposed to discipline the political and economic systems through market mechanisms. Until the mid 1990s, structural adjustment programs were still the main tool for both development strategies and foreign aid. However, since the late 1990s, it became obvious to many, including the World Bank and the IMF themselves, that if foreign assistance to developing countries was to continue it should retake poverty reduction strategies.

Today, the so-called Millennium Development Goals are the target toward which the United Nations and the international community’s endeavors are directed, becoming the actual core of the hegemonic discourse. The first of these goals is to halve global poverty and hunger by 2015.

**Geographies of Foreign Aid**

Little work in the discipline of geography has been done on the study of spatial distributions of foreign aid. Most of the studies that explored the issue from a geographic perspective are dominated by disciplines such as international relations and political science.

Nevertheless, a brief look at foreign aid flows during the postwar period reveals that the bulk originates from the 22 DAC members, which consist of the 15 original European Union members, Australia, Canada, Japan, New Zealand, Norway, Switzerland, and the United States. Among these, the United States contributes the most, followed by Japan and the EU members.

In absolute terms, foreign aid has grown since the 1960s. There is a clear decline, however, when foreign aid is measured as a proportion of the gross domestic product (GDP). The figure is far below 0.7%, which is the goal set by the OECD. Between 1990 and 1996, the average GDP proportion for the DAC members declined from 0.33% to 0.22%. Today, only a few DAC members, such as Norway, Denmark, Luxembourg, Sweden, and Holland, are fulfilling the goal of 0.7%.

From the recipient perspective, the inflows have been quite diverse for the different regions. The most populated region, Asia, has received much less foreign aid per capita than both Africa and Latin America. Between 1960 and 2004, the inflows to Asia have been very stable and low, always below $1 per capita. Paradoxically, the material and economic conditions, especially the economic growth, are today far better in East Asia than elsewhere. This observation reemphasizes the idea that foreign aid is only one part of economic development and could never explain the motions of economic development per se.

It is worth noting that the practice of foreign aid is no longer exclusive to the developed world
as countries such as China, India, and South Korea are becoming important donors.

**Controversies**

After more than 50 years and more than $1 trillion spent on foreign aid, there is still no compelling evidence that aid promotes economic development. Many scholars suggest that foreign aid can only play a modest role. Endogenous factors such as the institutional environment and the competence and goodwill of the leadership are crucial. Much research claims the relevance of the above-mentioned factors; some refer to them as the *absorptive capacity* of recipient countries. However, opinions differ on how the donor community should proceed. There are those who underline the opportunities that an increase in foreign aid could ensure, while others draw attention to the negative effects it might engender. The first group claims that with an increase in foreign aid combined with better donor coordination, foreign aid can improve the economic situation in recipient countries. In opposition, the latter group suggests that with more foreign aid, dependency will grow stronger, while the capacity to mobilize domestic resources, to create a national economic basis, and to compete internationally will be drastically diminished. These critics also warn that corruption may increase in the foreign aid chain.

*Yahia Mahmoud*

See also Developing World; Development Theory; Organisation for Economic Co-operation and Development (OECD)

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**Foreign Direct Investment**

Foreign direct investment (FDI) occurs when a foreign investor exerts direct control over domestic assets. It normally consists of an international capital flow from the home country to a host country for the purpose of acquiring partial or full ownership of tangible business activity. Technically, it is the book value of the equity held by the foreign investor that is attached to the asset. In most cases, the asset is a firm in a developed country, such as the United States, and the equity consists of two components: ordinary (common stock) and retained earnings. If both foreign and domestic investors own the common stock, then only a portion held by foreign investors is considered to be FDI, and if only a threshold percentage is attained, that is deemed to give the foreign investor control of the business. In the United States, this threshold is 10%, but some countries establish a higher minimum level of stock ownership, usually 25%.

Foreign investment can take place in two ways: Foreign investors can establish new firms overseas, which they control, or foreign investors can acquire controlling interests in the previously established domestic firms, or spin-offs of such firms. FDI as a vehicle of transnationalization is a major contributor of economic development. Transnational corporations (TNCs) act as significant transmitters of economic, social, cultural, and political change into different countries, sectors, and motivations. TNCs take advantage of geographical differences in the distribution of factors of production (natural resources, capital, labor, etc.) and local policies (taxes, trade incentives, subsidies, etc.). Other than FDI, TNCs engage in various kinds of collaborative ventures by which they coordinate and control transactions within geographically dispersed production networks. Resulting from these ventures, the global economy is envisaged as linking together two sets of networks: (1) organizational (in the form of production circuits and networks) and (2) geographical (which include localized clusters of economic activity).
Theories of Foreign Direct Investment

There are several theories that attempt to account for foreign aid. The prevailing ones include Dunning’s eclectic approach and the product cycle. John Dunning’s eclectic paradigm emphasizes the critical role of geographical location in understanding the complex nature of TNC behavior. The location aspect, as encapsulated in this theory, suggests three primary motivations: (1) foreign-market-seeking FDI, (2) efficiency (cost reduction)-seeking FDI, and (3) resource-seeking or strategic-asset-seeking FDI. In general, a firm’s motivations to be transnational can be classified into two categories: (1) market orientation, which pertains to marketing, sales, or production designed to serve a specific geographical market, and (2) asset orientation, when most of the assets required by a firm to produce and sell specific goods and services have an uneven geographic distribution, especially in the natural resources industry. For a TNC to invest successfully abroad, it must possess advantages that no other firm has, the country it wishes to invest in should offer location advantages, and it must be capable of internalizing operations. Internalization tends to become synonymous with the ability of firms to exercise control over operations essential for the exploitation of ownership and location advantages. Raymond Vernon introduced the “locational” aspect to the product life cycle concept, which in the original form had no spatial connotation. First advanced in the mid 1960s, it emanated from the premise that the United States possessed comparative advantage in product innovation. To maximize production flexibility and minimize uncertainties in the early stages of a product’s life cycle, firms develop innovations for and introduce them to large high-income domestic markets but eventually set up foreign production facilities in other advanced economies to defend their monopolistic advantages resulting from an innovational lead. This also happens because, as products become more standardized, they get more price sensitive and firms turn to low-cost less developed countries (LDCs) to maximize profits. Vernon describes the phases as revolving around product development, product growth, product maturation, and product standardization.

Impacts of FDI

However, not all FDI is always in the best interest of the host country. Some nations have been increasingly viewing TNCs as a threat to economic autonomy. At times, they tend to be responsible for exerting negative influences on the host economy, for example, crowding out domestic firms and suppressing domestic enterprises. Profit maximization is inherently linked with maximization of efficiency and not necessarily with national, economic, and social goals. From the perspective of TNCs, various decisions have to be taken that can affect their effective working in the country—mainly since they operate in different economic, political, social, and cultural environments.

A lot is said as to why firms choose to transnationalize rather than simply export their products. Two of the reasons commonly cited are that (1) competition is extremely global and volatile and (2) it creates an environment wherein advantages are rapidly created and eroded. Firms increasingly compete not with rivals on a national level but across the globe. Higher sales and profits result from foreign subsidiaries because domestic markets, where the company started, tend to get saturated over time and it is fruitful to conquer foreign markets with more potential consumers than in the home country. The information technology revolution, which began in the United States in the 1980s, was an important source of structural change in the international economic and business environment affecting FDI. There was a sudden upsurge in asset-seeking direct investment in the United States. Foreign companies, chiefly European, were responsible for a gamut of mergers and acquisitions with U.S. companies—primarily with those possessing advanced technology or marketing prowess. The size and growth of the U.S. and Chinese markets have made these countries primary destinations for foreign companies using FDI as a stimulus for profits.

Importance of FDI

FDI has been known to provide a longer-term contribution to GDP and income growth, as against bank loans and portfolio investments.
The long-term perspective of FDI makes it relatively less volatile. FDI is considered to be an important carrier facilitating the spread of technology and is said to contribute to growth in a much wider way than does domestic investment. The contribution of FDI is enhanced due to the interactions with human capital in the host country.

Furthermore, FDI is said to expand the level of know-how in the host country through training and skill acquisition. Summarily, the four basic reasons why companies establish subsidiaries in foreign countries are (1) gaining access to natural resources, (2) protecting or expanding sales in lucrative markets, (3) seeking low-cost production, and (4) acquiring strategic assets. The United Nations, the European Union, and Japan have been the main sources and recipients of FDI for the past several decades. From 1998 to 2000, these three units together accounted for 75% of global FDI inflows. In totality, a country’s climate for FDI is built by factors such as relatively accommodative government policies—covering trade barriers and regulation of capital inflows; quality of governance; political stability; presence of laws and regulations; macroeconomic, fiscal, monetary, and industrial policies; and quality of infrastructure.

Foreign Direct Investment in Emerging Economies

The United States continues to be the largest FDI host country, with about US$2791.3 billion in 2007. The outward investment position increased to US$336.6 billion. Among the outward investments, about US$16.1 billion (3.1%) went to Ireland and US$4.2 billion (3%) to Singapore.

Among emerging economies, China’s role as an investor country has been highlighted in the past few years. By 2004, China was the eighth most favored FDI source among developing countries. The liberalization of Chinese FDI policy in 1992 led to increased Chinese outward direct investment (ODI). The growth in Chinese ODI policy developments was driven by cautious internalization, government encouragement, expansion and regulation, implementation of a “go global” policy, and heightened domestic competitive pressures, which led to the opening up of protected industries and markets to foreign and domestic competitors. A comparative advantage as a manufacturing hub and a firm-specific advantage such as state-ownership of a large part of an industry further stimulate this growth. Chinese ODI has been positively associated with Chinese exports to the host country (the former promoting the latter), a moderate demand of inflation, and rising levels of political risk in the host country. A distinctive feature that remains with China as against other emerging economies is that many of its multinational enterprises remain in state hands, although corporatized to focus on commercial objectives. China’s overall FDI inflows stood at US$82.7 billion, an increase from US$69.47 billion. The top 10 FDI inflows were mainly from Hong Kong, the British islands, South Korea, Japan, Singapore, and the United States, amounting to about US$3 billion in 2006 and about US$2.62 billion in 2007. According to the Ministry of Commerce of the People’s Republic of China, the outbound nonfinancial FDI for the first half of 2007 reached US$7.8 billion, while for the full year in 2006, it was US$21.2 billion. Of this, 86% was provided by central government sources. Most of China’s ODI flowed to 172 destinations, which included Latin America and Asia. In India, the overall record of macroeconomic stability, a sizable domestic market, and a relatively high degree of political stability has attracted large volumes of FDI. The foreign investment in India during 2007–2008 was driven by FDI and portfolio investment inflows. FDI inflows in India increased from US$9.17 billion in 2005–2006 to US$22.95 billion in 2006–2007 and US$34.92 billion in 2007–2008. India emerged as the second most favored FDI destination after China in 2005 and 2006. During these years, investments through Mauritius remained the largest component, followed by Singapore, the United Kingdom, and the Netherlands. Inflows from the United States stood at the sixth position at US$3.46 billion in 2005–2006, US$7.06 billion in 2006–2007, and US$4.86 billion in 2007–2008. Sectorwise, these inflows were mainly directed to financial services, construction, and manufacturing. On the other hand, ODIs from India increased from US$13.5 billion during 2006–2007 to US$17.9 billion during 2007–2008 and flowed mainly into the manufacturing sector.
Within the European Union, Ireland is fast emerging as the most FDI-intensive economy in Europe and a global competitor to R&D investment. Since the 1990s, Ireland’s economic development policies, which have encouraged greenfield investments by foreign companies in manufacturing and service sectors so as to produce output for export markets, and the establishment of upstream linkages between foreign and indigenous companies and the creation of industrial clusters with them have stimulated an export-led growth of the manufacturing sector. In Singapore, another emerging FDI destination, the total ODI was recorded at US$406.7 billion in 2005 and US$484.1 billion in 2006. Financial services and manufacturing have been major draws for Singapore companies venturing abroad. In 2005 and 2006, Singapore invested about US$9.8 billion and US$8.5 billion in the U.S. market. The FDI inflow in Singapore was at US$323.8 billion and US$363.9 billion, the FDI inflow from the United States alone constituting about 10% of this inflow.

The current scale, proliferation, and importance of collaborative ventures between firms across boundaries have brought out the significance of transnational strategic alliances between firms (especially competing firms). Strategic alliances are formal agreements between firms to pursue specific strategic objectives in order to enable them to achieve specific goals. It involves sharing of risks and rewards. For R&D ventures, for example, cooperation is limited to research into new products and technologies, while manufacturing and marketing remain the responsibility of individual firms.

Globalization, technological advances, and the emergence of new players have propelled a change in FDI movement. Globalization, by removing most of the natural and artificial barriers to cross-border information flows and transactions, has widened locational choice options for firms. By lowering transport, communication, and distribution costs, technological advances have helped overcome many obstacles to overcome space.

Sharmistha Bagchi-Sen and Dipti Saletore

Further Readings


**FOREST DEGRADATION**

Forest degradation is not a reduction of forested area but a decrease in its quality, a significant decline of its ecological condition, and/or a shift in its structure. In most cases, human-related activities are the cause of forest degradation. Parameters triggering forest degradation can be local (stand disturbances, insect outbreaks) or regional (climate change). Estimating the extent of forest degradation is challenging because it is difficult to describe the initial state of the forest and the equilibrium state (i.e., climax condition). Also, time-related problems arise due to the

See also Export-Led Development; Globalization; Neocolonialism; Trade; Transnational Corporation
Forest Degradation in the Northern Hemisphere

As the Pleistocene glaciers began to retreat gradually about 18,000 years ago (BP), species of the boreal forest began to move northward in North America and Eurasia. Around 9,000 BP, milder climatic conditions favored expansion of dense forests in northern areas. Since then, the climate has changed, and the ecological conditions allowing northern expansion of forests no longer prevail. These trees were established during warmer climatic episodes a few hundred to a few thousand years ago and have persisted by vegetative reproduction. Presently, boreal forests occupy about 17% of Earth’s total land surface in the Northern Hemisphere.

The North American boreal forest belt is represented by three zones: (1) the closed-crown forest

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Figure 1  Model of stand disturbances causing the shift of the closed-crown forest to the lichen-spruce woodland in the closed-crown forest zone


Notes: The continuous black arrows indicate good regeneration, whereas the black dotted arrows indicate poor regeneration of the closes-crown forest. The dashed black arrows represent a short interval between two disturbances (compounded disturbances). The dashed and dotted arrow indicates a possible reversion of the lichen-spruce woodland into a closed-crown forest.
zone, (2) the lichen woodland zone (or taiga), and (3) the forest-tundra zone. The closed-crown forest zone is the southernmost portion of the boreal forest. It contains the greatest richness of species, the warmest soils, the highest productivity, and the longest-growing season. North of the closed-crown forest zone is the lichen woodland zone, represented by open, sparse forest. To the north of the lichen woodland is the forest-tundra zone, which occurs along the northern edge of tree growth or tree line. Patches of trees consisting of only a few species form a complex mosaic with the tundra. Boreal forest is characterized by a limited number of conifer species such as pine (Pinus), spruce (Picea), larch (Larix), and fir (Abies) and several deciduous trees such as birch (Betula) and poplar (Populus).

Northern forests do not have a rich and complete vegetative cover due to the extreme environmental conditions, such as harsh winters, a short growing season, a high altitude, and thin soils. This particular characteristic makes them vulnerable to forest degradation. In fact, these stands usually grow and develop under an active disturbance regime including wildfires, insect epidemics, and logging. Both conifer and deciduous species can regenerate after stand disturbance to minimize forest degradation. Following a fire, however, several conditions have to be met to facilitate adequate forest regeneration: (a) the trees have to be old enough to reproduce; (b) the trees have to be in good health, that is, not affected by insects or viruses; (c) the seeds need an adequate seedbed for germination, that is, the mix of mineral soil and organic matter; and (d) there must be a dense prefire tree cover. These conditions are more important for monospecific stands because regeneration failure of the dominant species induces forest degradation.

Closed-crown forest degradation in the black spruce stands of Eastern Canada involves stand disturbances (Figure 1). The transformation of the closed-crown forest in lichen-spruce woodland is the consequence of a regression process of the boreal forest triggered by stand disturbance. Generally, natural or anthropogenic disturbances ensure stand regeneration. At the other end, compounded disturbances cause the degradation of the closed-crown forest. A short interval between two disturbances can compromise the reestablishment of the closed-crown forest. Disturbances that affect the vitality of trees in the stand, such as an insect infestation, followed shortly thereafter by a fire, can greatly increase the probability of reduced tree regeneration. A reduction in the tree density of a stand can sometimes be caused by a spruce budworm epidemic followed by logging (salvaging of dead timber or affected trees). The passage of successive fires, that is two fires arriving at an interval too short for the trees to attain maturity and reproduce, can equally cause drastic reduction in tree regeneration. Also, the passage of light fires that leave a thick organic matter layer increases forest degradation mainly because seed germination is facilitated on mineral soils where the organic matter was consumed by fire. Finally, degradation of a closed-crown forest into a lichen-spruce woodland appears to be a unidirectional process; to date, the reverse process, the transformation of a lichen-spruce woodland to a closed-crown forest, has not been observed. Once degraded into an open stand, the southern lichen-spruce woodlands resemble the lichen-spruce woodlands situated within the lichen woodland zone. The absence of the full reestablishment of closed-crown forest following a fire is equally characteristic of the regeneration pattern of the forests growing within the lichen woodland zone.

The increasing extent of lichen-spruce woodlands within the southern forest zone is a major problem for forest management, which will intensify if the present degradation trend is maintained (i.e., 9% since 1950 in Eastern Canada). Lichen-spruce woodlands are not economically exploitable for foresters, likely because of their low timber yield, which is below the threshold of durable management. Restoration of degraded forests is possible with plantation, but adequate ground preparation is required (soil scarification). Finally, tree plantation in degraded areas reduces soil erosion and decreases the probability of landslides.

François Girard and Serge Payette

See also Anthropogenic Climate Change; Biome: Boreal Forest; Biome: Tropical Rain Forest; Deforestation; Ecosystems; Forest Fragmentation; Forest Restoration; Global Environmental Change; Landscape Ecology
Forest fragmentation is an aspect of deforestation. It refers to the conversion of relatively continuous forests into a system of isolated forest patches separated by agricultural, urban, or other human land use. The forest remnants may represent areas unsuitable for conversion for economic, physical, political, or cultural reasons (e.g., because of steep terrain or for nature preserve creation). Forest fragmentation is pervasive worldwide. Large-scale forest clearance and fragmentation began in parts of Europe and Asia that had long histories of dense human settlement. It spread to North America during the European settlement about 200 to 300 years ago, beginning with the eastern and midwestern forests (Figure 1). While the abandonment of marginal farmland later facilitated reforestation of some areas, many areas remain where the forest cover represents less than 30% of the landscape. Reforestation has not necessarily reduced fragmentation. In some parts of Southern Ontario, for example, fragmentation has increased in recent decades even while the total forested area has increased. The tropics are the locale of the most widespread and rapid current or recent deforestation. This is ecologically significant because although tropical forests constitute less than 10% of Earth’s land surface, they house more than half of its biological diversity. Much of Central and South America (Brazil) and southeast Asia (e.g., Malaysia, Indonesia, and Papua New Guinea) have rapid current rates of forest loss. Deforestation has slowed in areas such as West Africa, Thailand, the Philippines, and Madagascar, but these places had already lost most of their natural forest cover by the last third of the 20th century.

Forest fragmentation involves changes in (a) the spatial population dynamics of species in fragmented systems and (b) the biophysical environments of fragments.

Changes in Population Dynamics

In many landscapes, including North America and the tropics, fragmentation represents a relatively recent phenomenon in relation to the life spans of tree species, which constitute the bulk of forest biomass. It may take centuries for their populations to adjust to biogeographic changes, and so forest response cannot be deduced from simple measures of species composition in these systems. Theoretical constructs such as the equilibrium theory of island biogeography and other, subsequent, theoretical and computer simulation models of the behavior of disjunct populations or “metapopulations” predict that fragmentation will lead to species extinctions because dispersal among forest “islands” will be rare and insufficient to counteract ongoing local extinctions within fragments. This prediction assumes two characteristics of fragmented populations. First, population sizes in fragments are smaller and more extinction-prone than in continuous forests. Second, the long distances and potentially hostile matrix separating populations will hinder
interfragment dispersal and reestablishment. The combined effect is regional extinctions.

Recent studies show that plant colonization in forest fragments is hindered by limited long-distance dispersal. For many tree species of the eastern deciduous forest biome, for example, dispersal across distances of more than 100 meters is severely limited, especially among wind-dispersed species or heavy-seeded rodent-dispersed species (Figure 2). The former tend to get strewn in the intervening matrix, where they cannot establish, whereas the latter may be too heavy for animals to carry between fragments. Moreover, many tree species exhibit low rates of seedling establishment and survival in forest fragments (Figure 3). As a result, interfragment tree colonization is rare. Migration of some birds and mammals between fragments is also constrained by the risk of predation in exposed areas. However, connective vegetation structures such as hedgerows, fencerows, or riparian patches promote animal migration.
Some research suggests that fragmented habitats may provide compensatory effects that buffer species from regional extinction. This research centers on the design of nature preserves and the question of whether a single large preserve is more likely to sustain species than several smaller ones—the “single large or several small” (SLOSS) debate. Proponents of the “several small” position suggest that populations may be more likely to survive somewhere in the system in the event of disease outbreaks or natural disturbances such as fire and flood. Evidence to support this prediction is mixed. Among animal species, particularly birds, small oceanic archipelagoes with a greater degree of fragmentation have been found to support greater species richness. Similar results have been found for some understory herbaceous species. Beyond the SLOSS debate, studies of naturally patchy systems may help predict long-term effects. Forest patches concentrated along fire-protected river valleys in fire-prone landscapes in Belize and Venezuela exhibit high plant species richness compared with the nearby continuous forest. Conversely, experimental studies in human-fragmented systems indicate that the normal tendency is toward a lower species richness over time.

**Changes in Biophysical Environments**

Forest fragments are typically surrounded by a “sea” of human land use, whether agricultural, residential, industrial, or urban, which can alter the physical environments within. Much attention has been given to microclimatic changes near fragment edges. These “edge effects” include higher wind speeds and solar radiation at exposed edges than those in the shady, mesic forest interiors, with resultant lower relative humidities and soil moisture at the edges. These desiccating conditions tend to intrude tens of meters into fragment interiors. For plant species that are adapted to interior conditions, the suitable habitat may be restricted to a small “core” at the center of fragments, much smaller than the total forested area. Core species populations may not be large enough to remain viable over the long term, particularly in the case of rare species whose densities are low to begin with. There is, however, evidence that over time, plant species that thrive in sunny conditions may form a band of dense foliage at the edges that buffers the interior from edge effects.

The loss of forest interior habitat may also adversely affect forest bird species. Studies of
midwestern and eastern forests in North America indicate increased predation at the edges by animals, such as raccoons and crows, that are abundant in the adjacent farmland and increased nest parasitism, particularly by invasive cowbirds. The situation may be different in Western North America, however, where logging, rather than agriculture, is a common cause of deforestation and where forest environments are more naturally patchy as a result of historical fire disturbance and uneven topography. Western bird populations therefore seem to be better adapted to patchiness and have actually been found to experience lower mortality in fragments than in nearby continuous forests that harbor predatory red squirrels.

Figure 3  Probabilities of early seedling survival among native eastern tree species in Southern Ontario forest fragments

Source: Adapted from Hewitt, N., & Kellman, M. (2004). Factors influencing tree colonization in fragmented forests: An experimental study of introduced seeds and seedlings (Figure 12). Forest Ecology and Management, 191, 53.
Other environmental pressures on fragmented populations include the incursion of pesticides and other pollutants into forest habitat. Insect pollinators such as bees may be particularly sensitive to pesticides. These chemicals represent a real, but as yet poorly measured, threat both to insects and to the plant species they pollinate. In built-up areas, moisture conditions may be affected at a landscape level because of the prevalence of impermeable surfaces that prevent rainfall from infiltrating the ground and replenishing soils and water tables. Sites of small-scale human disturbance such as trails, roads, and forest thinning have been correlated with a reduction in native plant species. However, a disturbance such as selective tree cutting may facilitate the establishment of shade-intolerant species in some fragmented systems and so cannot be viewed entirely negatively. Finally, a fragmented forest is more vulnerable to exotic species invasions than is a continuous forest due to the greater edge-to-interior ratio and greater juxtaposition with human activities responsible for exotic species introduction. The problem of plant invasion is compounded by the preponderance of edge habitat, which provides favorable microenvironments for characteristically weedy, shade-intolerant invasive plant species.

**Implications of Global Climatic Change**

Global climate change and warming will exert further stress on fragmented forests by forcing the migration of species to higher latitudes. While the pollen record shows that temperate genera had remarkably rapid rates of northward migration during the most recent deglaciation in the Northern Hemisphere, they achieved this in a landscape uninterrupted by human land use. Forest fragmentation may represent a formidable barrier to migration in a warming climate.

_Nina Hewitt_

See also Anthropogenic Climate Change; Biome: Boreal Forest; Biome: Tropical Rain Forest; Deforestation; Forest Degradation; Island Biogeography; Landscape Ecology; Single Large or Several Small (SLOSS) Debate; Species-Area Relationship

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**Further Readings**


Forests are critical elements in the climate system and other global and local ecological processes, such as the carbon, oxygen, nitrogen, and water cycles. Forests influence the climate system largely by affecting the amount of carbon dioxide in the atmosphere. When forests grow, carbon is taken from the atmosphere and absorbed in wood, leaves, and soil. Because forests can absorb and store carbon over an extended period of time, they are considered “carbon sinks.” This carbon remains stored in the forest ecosystem but can be released into the atmosphere when forests are burned. Forests are critical to humans not only as providers of ecosystem services (e.g., provision of clean water and air) but also as a critical resource for human livelihoods since forests are also home to other organisms that provide important resources to humans.

Forests are used primarily for their wood and, after forest cover is removed, for agriculture. However, forests play a very important role in subsistence economies across the world, from boreal forests to tropical forests. Communities in Alaska, for example, use boreal forests as a source of food, shelter, transportation, and clothing. In the Amazon, many communities rely on forests not only for their subsistence but also for important market commodities such as rubber and Brazil nuts. In the United States, national forests are considered an important source of local products as in subsistence practices in tropical areas; a specific example is the extraction of edible mushrooms (e.g., morels) in national forests in the Western and Eastern United States.

The use of nontimber products from the forest is considered a sustainable alternative to the conflict between indigenous forest dwellers and conservation practices. Many communities (especially in the tropical regions) depend largely on their ability to gain livelihood resources from their immediate environment. The extraction of nontimber forest products is considered a sustainable activity as long as forest dwellers do not compromise the resource base. One of the major criticisms of the sustainability of nontimber product production is the lack of improvement in the lives of poorer, resource-dependent communities due to the absence of markets, relegating this to a safety net activity and a supplemental income source. The question remains whether resource availability necessarily provides the context for significant contributions to the well-being of communities that rely on forest resources.
Changes in Forest Spatial Coverage

The land area covered with forest has diminished over time. The most common land changes in the world are the transformation of forests into agricultural and urban areas and land under other types of uses. Since 1700, approximately 10 million km² have been transformed mostly into agricultural land used to produce food for human consumption. Forest change is measured by the forest density (the number of individuals and species per area) and by the amount of area covered by it. Based on these two measures, there are four different states or processes of forest transitions: (1) deforestation, characterized by decreasing forest area and density; (2) reforestation, characterized by increasing forest area and density; (3) regeneration, characterized by decreasing forest area and increasing forest density; and (4) degradation, characterized by increasing forest area and decreasing forest density.

Such events occur simultaneously in several world regions. Yet deforestation has gained the most attention because of its ecological and social implications. Globally, the net deforestation is greater than any of the other forest transitions described above. The decrease in primary forest is around 12.5 million ha/yr. (hectares per year), and deforestation is around 14.6 million ha/yr. Conversion to forest plantation is growing at 1.5 million ha/yr., around 3.1%; plantations in areas previously removed from forest, however, account for half of the net increase in forest plantations, according to Helmut Geist and his colleagues. Most of the deforestation occurs in the tropics, and most of the regrowth occurs in Western Europe and Eastern North America. Monitoring forest transitions is challenging because it requires the use of different methodologies to reduce uncertainty in the estimates. The most common techniques used to measure deforestation are forest inventories, forest plantation data, and, with technological improvements, the use of remote sensing surveys.

If monitoring the actual change of forest cover is challenging, elucidating the social drivers of such change is even more difficult. For example, the drivers of deforestation are divided into proximate and underlying processes (social and ecological). These drivers also operate at the local, regional, and global scales. The critical element in understanding forest transitions is to determine how people make land use decisions, how biophysical settings relate to such social processes, and how they interact in specific contexts at different scales of analysis. How much forest is used or transformed relates directly to immediate actions that originate from forest manipulation (e.g., logging, extraction of nontimber products, and development of new infrastructure). It is important, however, to consider the root or the indirect drivers of such complex social, political, economic, demographic, and cultural variables (e.g., agricultural polices, markets, governance). As an example, tropical deforestation is mostly driven by forest commercialization through the growth of national and international timber markets, low domestic costs of land and labor, and fluctuations in the price of agricultural commodities.

Conclusion

The world’s forests are critically important to the functioning of the Earth and for sustaining human livelihoods. Forests provide renewable raw materials and energy, maintain biodiversity, and protect land and water resources. However, they are being diminished by agricultural and urban expansion or degraded by wood extraction. Policy mechanisms such as the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries are being sponsored by international institutions such as the United Nations Framework Convention on Climate Change to provide ways to conserve forests and benefit communities that rely on forest resources. How successful such programs are in preserving forests, while not conflicting with the subsistence practices of indigenous communities, remains to be seen.

Laura C. Schneider

See also Biome: Boreal Forest; Biome: Midlatitude Deciduous Forest; Biome: Tropical Deciduous Forest; Biome: Tropical Rain Forest; Deforestation; Environmental Services; Forest Degradation; Forest Restoration; Indigenous Forestry; Timber Plantations
The widespread destruction of habitats and the associated loss of species have resulted in the development of ecological restoration projects worldwide. The restoration of degraded ecosystems can serve to improve not only the conservation of species but also ecosystem productivity and the welfare of human communities affected by those ecosystems. The Society for Ecological Restoration International defines the practice of ecological restoration as “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.” Forest restoration represents a particular type of restoration practice.

### Further Readings


### The Need for Forest Restoration

An extensive body of scientific evidence indicates that preservation of biological reserves is not enough to stem the current biodiversity crisis. While preservation of forests in parks, reserves, and wilderness areas is critical, these landscapes are too fragmented and too small in area. Restoration of degraded and damaged forests is necessary to enable humans to sustainably live and work in ecosystems. Restoration also provides buffers and corridors for added protection and migration of species within protected areas. Forest restoration contributes to poverty reduction and prevention through the protection of water resources, mitigation of soil erosion, and provision of natural resources. Furthermore, restoration of forest ecosystems and corridors will mitigate the impacts of global climate change by enabling forest systems to respond better to stress and change and provide increased carbon sequestration and storage.

### Implementation of Forest Restoration

The goal of forest restoration is not to replicate historic forest structure and composition. Given the complexity of forest systems and the multitude of compounding human impacts, it is unlikely that forests can be fully returned to historical conditions. And this is not a desirable goal in the face of uncertainty in predicting the impacts of global climate change and the increasingly multifaceted demands on forest resources (e.g., conservation of biodiversity and poverty alleviation). Rather, the goal of forest restoration is broadly conceived as the restoration of ecological processes and functions that will enable forest recovery.
Forest restoration represents a long-term management commitment at multiple scales by numerous, often competing stakeholders. The most successful restoration projects fulfill social and conservation needs simultaneously, thereby ensuring the ongoing support needed to sustain the species and people dependent on the forest. Key elements of successful restoration typically include consensus planning, use of local knowledge, educating community members about environmental degradation and restoration, and ongoing monitoring. Forest restoration projects are more effective when they are considered components of continuing land management rather than isolated projects with definitive end points.

A Case Study of Forest Restoration

One of the longest-running and well-documented forest restoration projects exists in Redwood National Park in northwestern California. This national park was the first in the United States mandated to undertake an extensive forest restoration and rehabilitation program. Since 1978, Redwood National Park has used cutting-edge restoration techniques to protect its old-growth coast redwood forests and rehabilitate logged-over lands. Indeed, the national park has been at the forefront in the promotion and development of watershed-scale restoration, gaining international recognition for its forest restoration work.

Jon Kyl (R-AZ), left, and Secretary of Interior Gale Norton view the 12-acre Gus Pearson Natural Area, August 8, 2001, in Flagstaff, Arizona. Both Kyl and Norton were surveying the experimental forest inside the Coconino National Forest to see firsthand the forest restoration techniques and how they might be implemented in other states.

Source: AP Photo/Matt York.
As in most forest restoration projects, the work in Redwood National Park is facilitative. Restoration begins on the ground with physical rehabilitation of destabilized slopes and degraded soils and new recruitment of existing and reintroduced plants. To the extent to which it is feasible, removal of exotic species occurs concurrently. These steps enable biological restoration activities, such as accelerating the improvement of the habitat for endangered species and the integration of contemporary indigenous values in vegetation management. Restoration silviculture in the park aims to speed the development of old-growth forest wildlife habitat in second-growth forests through selective removal of trees that inhibit recovery. Restoration of ethnographic and cultural landscapes involves encouragement of traditional Native American land uses (e.g., management of hazel patches for basket-weaving materials) while restoring degraded ecosystems (e.g., prescribed burning of prairies and oak woodlands). Redwood National Park’s continual emphasis on the reintroduction of processes such as disturbance agents serves the dual mission of the park—preservation and visitor enjoyment of park resources—and enables land managers to respond to changing environmental conditions.

Joy A. Fritschle

Further Readings


FOTHERINGHAM, A. STEWART (1954–)

Alexander Stewart Fotheringham is one of the most active researchers in geographic information science. His research includes spatial statistics, exploratory spatial data analysis, spatial interaction modeling, and spatial analysis. He is
one of the codevelopers of geographically weighted regression (GWR).

Fotheringham received his PhD and MA from McMaster University in Canada and his BSc from Aberdeen University, United Kingdom. Since 2004, he has been Science Foundation Ireland Research Professor and director of the National Centre for Geocomputation at the National University of Ireland, Maynooth. He leads an active research center, which since 2008 includes the Strategic Research in Advanced Geotechnologies group, consisting of researchers from four Irish universities working on four interconnected research strands: sensor integration, spatial algorithms, spatial visualization, and location-based services. Previously, he was professor of quantitative geography at the University of Newcastle, United Kingdom, held positions at several universities in the United States (State University of New York at Buffalo, University of Florida, and Indiana University), and was a member of the National Center for Geographic Information and Analysis. He is one of the founding editors of Transactions in GIS and an associate editor of Geographical Analysis. He has published numerous books and more than 100 journal articles. He has received numerous awards, including a fellowship from the Center of Advanced Study in the Behavioral Sciences at Stanford University, United States; the PHIAL (Public Health Intelligence Applications Laboratory) Fellowship from Victoria University of Wellington, New Zealand; and a Leverhulme fellowship.

His early work was primarily in spatial interaction modeling. Spatial interaction is defined as movement or communication over space resulting from a decision-making process. This analysis has a wide range of applications, for example, migration modeling, shopping behavior, and commuting. Fotheringham introduced a new type of spatial interaction model, the competing destination model, that linked spatial interaction analysis to spatial information processing.

Subsequently, Fotheringham’s research emphasized spatial statistics, and in the mid 1990s, he introduced a new local spatial statistical method, GWR, together with his colleagues Martin Charlton and Chris Brunsdon. GWR is a spatial regression technique that removes the necessity of assuming that spatial processes are the same everywhere and allows local modeling of such processes. Since its introduction, GWR has become one of the standard spatial analysis tools. Fotheringham continues to work on related topics, such as other geographically weighted spatial statistical methods, spatiotemporal extensions, and methodologies for easier interpretation of GWR output. He is also developing interests in spatial data capture technologies and spatial surveillance.

Urška Demšar

See also Geographically Weighted Regression; Geostatistics; National Center for Geographic Information Analysis; Quantitative Methods; Spatial Analysis; Spatial Interaction Models; Spatial Statistics

Further Readings


FRANK, ANDREW (1948– )

Andrew U. Frank has been a professor and the head of the department of geoinformation and Cartography at the Vienna University of Technology in Austria since 1999. He has been a leading theoretician and practitioner in the area of spatial data analysis and geographic information science (GIScience).

Frank received his doctoral degree from the Swiss Federal Institute of Technology, in Zurich, in 1982. Prior to joining the Vienna University of Technology, he had been on the faculty of the department of surveying engineering at the University of Maine. He has supervised
nearly 40 PhD students, many of whom are now leaders in GIScience. In 2005, he was awarded the national medal, “Grosses Silbernes Ehrenzeichen,” by the president of Austria for his contribution to science.

Earlier in his academic career, Frank made major contributions to the theory and application of spatial databases through a series of influential works on spatial data modeling, spatial data management, spatial data query, and interface design. Subsequently, his interests expanded into the areas of quantitative reasoning and natural linguistics in search of computational models for representing and processing uncertain and imprecise geographic phenomena. His ideas are expounded in his 1996 article “Qualitative Spatial Reasoning: Cardinal Directions as an Example,” which was selected as one of the 19 “most significant and influential articles ever” published in the *International Journal of Geographical Information Science*.

Frank’s more recent research efforts have been directed toward category theoretic formalization of conceptual models of geographic spaces, objects, and their relations, as well as the ontological aspects of geographic information. In particular, the geospatial information community has found highly insightful his idea of viewing the geographic world from different tiers of ontology, which helps articulate where and how inconsistency between data and reality occurs and propagates in geographic information systems (GIS). Frank has also been recognized as a major contributor to the birth and growth of this relatively new interdisciplinary field, namely, GIScience. Most notably, he is a cofounder of the National Center for Geographic Information and Analysis, a research consortium in GIScience formed by the University of California, Santa Barbara, the University at Buffalo, and the University of Maine. Also, in cooperation with others, he established the International Conference on Spatial Information Theory, a leading conference series on GIScience and related disciplines. In addition, he has served in the committees of a number of international conferences and journals. He is currently editor-in-chief of *Geoinformatica* and coeditor of *International Journal of Applied Earth Observations and Geoinformation* and is on the editorial boards of *Geographical Systems, International Journal of Geographical Information Science, Journal of Spatial Cognition and Computation*, and *Annals of the Association of American Geographers*.

*Takeshi Shirabe*

See also GIScience; National Center for Geographic Information Analysis; Ontology

Further Readings


The frontier is a core concept in geography. Its meaning denotes location at the outer edge of territory, but its use and significance derive from two separate traditions, one associated more with Europe and the other with the United States, although the term applies to regions across the world. The European usage focuses on the frontier as a political boundary between places, a line of separation; the American frontier emphasizes interactions within the borderland of settlement. The meanings grow from the different historical experiences and traditions that are involved in their interpretation. A frontier can be a line or an area, its location and extent stable or changing. The relationships along it can be amicable or confrontational, can flow through or across and are easily or tightly controlled. Although a frontier is a spatial periphery, it can be among the most critical of regions in the way it draws interest and resources from the core in the core powers’ attempt to control and manage it.

The European frontier is associated with boundaries between principalities or states—the outer limits of the Holy Roman Empire, say, or
the boundary between Normandy and Brittany. The word frontier reflected difference but did not dictate the degree or significance of that difference. As 18th-century Europe became a distinct set of nation-states, with more politically homogenized space and regularized borders, the term denoted regions elsewhere. The word indicated the speaker’s perception of a little known, lightly occupied area, potentially rich in resources, possibly an object of colonization. To Europeans, the Americas were frontier territory.

Within North America initially, European settlers, and later Americans, saw the frontier beyond their own permanent settlements, demarcating divisions between Native American space and their own, the boundaries quite close. The term was a European import to the Americas, and like other cultural imports, it gradually transformed in its new home. After independence, the U.S. preoccupation with national expansion made the frontier a central concern. The term meant the area in the process of incorporation into Euro-American settlements. The American frontier crossed the Appalachian Mountains and kept pushing west. It was characterized by spatial elasticity rather than fixity.

Throughout the 19th century, the American government used its decennial censuses to keep track of its population’s westward movement. Each census showed the country’s center of population and outer edge drifting west. The census even established a clear statistical measure for the frontier: an area with a population density between 2 and 6 people per square mile (a higher density meant that it was settled; a lower density meant a wilderness). Maps showed the national territory divided by settlement category as well as a frontier line, the contiguous edge between frontier and wilderness.

Native American settlements and people became synonymous with the frontier, the whole process of expansion presuming their displacement. Their boundaries, once loosely fixed, kept changing—but in their case, retreating. Throughout the 19th century, references to the frontier increasingly coupled Indians and disputed space. In his famous 1893 essay “The Significance of the Frontier in American History,” Frederick Jackson Turner, the foremost historian of the frontier, described the frontier as “the meeting place of civilization and savagery,” Euro-Americans and Indians. The frontier drew the former, looking for land and opportunity. Promoters described the frontier as ripe for appropriation and transformation and applauded those moving in as benefiting both themselves and the nation.

By 1890, the frontier area seemed integrated into the rest of the country. Its population was growing. In many places, its native grasslands had been converted to agricultural fields. The whole country became crisscrossed with railroad tracks. Turner saw the moment as transformative, and his 1893 essay described America’s frontier as closed. He argued that the country had become more like Europe in its settled borders but that its frontier history made it different in important ways. America was no longer a nation with a frontier, but it was still a frontier nation—its repeated waves of frontier expansion had fostered a buoyant, practical, and unrestrained national character that would persist after the presumed disappearance of the spatial frontier.

Turner was so persuasive that for the next century the frontier’s geographical significance received little new consideration. Yet much of the American West and the far northern borderlands never rose above the censuses’ frontier densities, and by the late 20th century, the population decline had become so severe in some areas of the Great Plains that they again had frontier densities. Many U.S. frontier communities remain distinctive for their small, isolated populations. Their poor transportation connections meant less access to the usual goods and services other Americans expect from business and government. These frontier regions cannot reliably count on good Internet connections or full-service health facilities.

While the United States has a “hidden” frontier, Amazonia is regularly described as a contemporary frontier. The vast tropical river basin of the Amazon still features a low population density, long-standing communities of native peoples, and ambiguous national borders difficult to police. As with the U.S. frontier, Amazonia’s natural resources, particularly rubber and gold, historically lured settlers from elsewhere. The low population density has similarly fed illusions of an unoccupied land that can be given away and cleared for agriculture. Such efforts were sporadic, but the past two decades’ soybean cultivation has
transformed sections of Amazonia, changing its landscape and economy, increasing its overall population and infrastructure development. The region’s largest city, Manaus, has become an export-processing center. Yet much of Amazonia remains heavily forested, low density, and remote. The region is known for its enormous biodiversity and vital role in global climate regulation and can survive only if conventional development is limited. Although most of the region lies within Brazil, it includes territory from eight other states, each with distant core areas. The borders between them remain areas of potential boundary conflicts and centers of illegal activities, such as cocaine production, that benefit from the peripheral location and weak control, classic features of frontiers.

Deborah E. Popper

See also Population Density; Settlement Geography

Further Readings


FRONTS

The most common definition of a front, which implies a sharp zero-order boundary, often leads to a misunderstanding of its concept and structure. A front is actually a human construct considered to represent the leading edge of a strong thermal gradient. As a result, it is very difficult to find consistency in its placement on weather maps, even by professional meteorologists. This is especially true with warm fronts.

Zero-order fronts are in fact rare, occurring most frequently during winter in the western high plains and prairies of North America as a result of the ebb and flow of chinook winds. Chinook winds are strong downslope westerly winds that force existing shallow arctic air masses to the east and then allow them to slosh back westward again when the winds weaken. The greatest temperature changes ever recorded in North America are in response to chinook-based zero-order fronts. For example, a 2-minute change of 27 °C (49 °F) was observed in Spearfish, South Dakota, on January 22, 1943, and a 24-hour increase of 56 °C (103 °F), from −47 to +9 °C (−54 to +49 °F) was noted at Loma, Montana, on January 15, 1972.

Compared with zero-order boundaries, most fronts are in reality a transition zone of significant horizontal planar extent, generally up to hundreds of kilometers in width with cross-sectional slopes and depths that vary with each individual air mass. For example, cold fronts generally exhibit slopes of between 30:1 and 50:1, while warm fronts are less steep, with ratios of 100:1 to 200:1. As a result, precipitation shields can extend more than 1,000 km ahead of surface warm fronts, while a cold frontal precipitation is generally of a much smaller horizontal extent and a shorter duration.

Another common misconception is that all fronts extend from the surface to the tropopause, when in fact this is found only with deep baroclinic cyclones. In many cases, upper-level and/or split fronts can pass through a region completely undetected by surface observation stations.

Split fronts exist in cases of differential advection, that is, when multiple air masses are moving through a region at different heights. For example, it is not uncommon for maritime tropical air to be moving north at the surface into the Great Plains of the United States from the Gulf of Mexico at the same time when a shallow layer of hot, dry
continental tropical air aloft is migrating northeastward from the mountains of Northern Mexico. In many cases, the shallow layer of hot, dry air arrives after the maritime tropical air at the surface, resulting in a split front structure. Split fronts are also common with winter storms in the Eastern United States, where the heaviest snowfall develops northwest of the surface cyclone center in response to frontogenesis at the 700-mb (millibar) level.

The precipitation that occurs in the immediate vicinity of fronts develops in response to baroclinic circulations that form as a result of increasing thermal and pressure gradients, such as with cold fronts, or due to steep isentropic gradients, as with warm fronts. It should be noted that not all precipitation with open-wave extratropical cyclones is frontal. This is especially true well ahead of either cold or warm fronts where isentropic lift due to significant south to north advection (tens of degrees of latitude) of moist air produces stratiform precipitation shields.

Fronts, whether they be cold, warm, occluded, or stationary, often trigger deep moist convection in conditionally unstable environments due to enhanced surface convergence. This generally occurs in discrete meso-gamma-scale areas due to the strength of the inversion that typically caps moist surface layers, and vertical directional wind shear. In cases where the inversion is weak and the wind shear is unidirectional, lines of convection quickly develop, in some cases becoming highly organized into a series of interacting cells. This type of organized convection is commonly referred to as a mesoscale convective system (MCS). Most mesoscale convective systems form just north of west-east-oriented warm fronts, migrating east-southeastward along the front and concluding their life cycles in the warm-air sector south of the front. While an MCS can produce large swaths of wind damage and flooding, in Central North America it also provides a significant proportion of the growing-season rainfall.

Although in some cases the precipitation ahead of cold fronts appears spatially contiguous, much of it is generated by isentropic ascent. Frontal lift (due to baroclinic circulations) generally produces a narrow band of precipitation only in the immediate vicinity of the front.

The location of frontal precipitation relative to the location of cold fronts varies a great deal. When the ascent slopes backward against the motion of the front, generally to the west with a typical north-south cold front, the stratiform precipitation shield is found mostly behind the front. This type of cold front is often referred to as an anafront. When the lift occurs in response to upright or sheared convection, it is found mostly ahead of the front, in some cases producing very heavy precipitation in spatial pockets, referred to as “maximum precipitation areas.”

### Warm Fronts

While cold fronts are the most common frontal types, warm fronts are not unusual, especially in Eastern North America, due to the east or southeastward movement of continental highs or northwestward expansion of the Azores’ subtropical high. In many cases, advancing cold air from the Western Cordillera in response to cyclones migrating southeastward from the Gulf of Alaska initiates lee-side cyclogenesis or storm “rejuvenation” east of the Rockies. This results in a warm front due to increasing pressure gradients between the lee-side low and the Gulf of Mexico.

In general, most textbook models of warm fronts imply the existence of only stratiform clouds and precipitation; however, surface convergence along warm fronts frequently triggers the development of cumulonimbus clouds. Given the easterly winds common in the vicinity of warm fronts, these environments are ripe for the development of supercells and tornadoes, given the magnitude of vertical shear.

### Cold Fronts

A cold front represents the leading edge of a thermal gradient in which cold air advection is occurring at Earth’s surface. Cold air advection typically results in baroclinic circulations that produce precipitation if enough water vapor is present.

### Occluded Fronts

Occluded fronts typically represent the “merger” of cold and warm fronts in response to the maturity of an extratropical cyclone. In the later stages of the Bjerknes cyclone model, cold fronts are expected to “catch up” with warm fronts due to their more
rapid movement. At this point, cyclolysis is expected to begin as the system becomes quasi-barotropic.

In fact, occluded fronts do not occur with every cyclone and are generally found in or near maritime environments since they represent cyclone maturity. In the middle latitudes of North America, they occur in the Eastern Pacific Basin and along the west coast as cyclones drop southward from the Gulf of Alaska. Along the east coast of the United States, very strong cyclogenesis can occur during the cold season, producing powerful “nor’easters” that move northward along the coast, with occlusion typically in Maine, Newfoundland, or Nova Scotia.

In special situations, especially over the ocean basins, small subsynoptic-scale polar lows develop north of the Polar Front jet as midlevel vorticity maximums merge with sections of existing fronts. These lows spin up so rapidly that it appears that the system is occluding almost instantly. As a result, polar lows are sometimes referred to as instant occlusions.

**Stationary Fronts**

Stationary fronts typically represent regions of strong thermal gradients in which neither warm nor cold air advection is occurring over significant periods of time. In reality, the positions of the thermal gradients tend to oscillate back and forth (from north to south with west-east aligned fronts) so that their mean positions appear to remain stationary. The physical structure of stationary fronts is much like that of warm fronts, and in fact, they tend to mark regions of significant isentropic lift, stratiform cloud, and precipitation development.

**Lift**

Most fronts produce lift in response to surface convergence only up to the 700-mb level (3,000 meters). In some cases, this is high enough to reach a favorable dendritic growth zone for snow; however, it is the transverse circulations in response to an upper-level jet maximum within the vicinity of the front that provide deep lift in which air can ascend from Earth’s surface to the tropopause. These transverse circulations produce a corresponding subsidence in other areas. As a result, there will appear to be an uplift/subsidence couplet within the region of a strong extratropical cyclone.

*David L. Arnold*

**See also** Adiabatic Temperature Changes; Air Masses; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Pressure; Atmospheric Variations in Energy; Clouds; Cyclones: Extratropical; Cyclones: Occluded; Differential Heating; Hurricanes, Physical Geography of; Monsoons; Precipitation Formation; Thunderstorms; Tornadoes; Urban Heat Island; Wind

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**Further Readings**


Gaia (or Gaea, from its roots Ge, “Earth,” and Aia, “grandmother”) is the name of the Greek goddess of Earth (cf. Tellus or Terra Mater [Latin], Bhumi Mata [Sanskrit]), who lends her name to geography and all the geosubjects. In Greek mythology, Gaea, born of chaos, gives birth to the sky, hills, oceans, and, eventually, time. Gaia is also the name given to a scientific theory of Earth that has given rise to a new kind of earth systems science, which puts biological processes in the driving seat. First formulated in the 1960s as the Gaia hypothesis by the British Earth scientist James Lovelock, its distinctive feature is that it conceives Earth as a biologically controlled (biocybernetic), self-regulating system. Gaia theory suggests that the biota, the sum of the planet’s living organisms, influences and regulates the global environment: atmosphere, temperature, water, air, soil, and, in effect, the whole global environment. It also suggests that the regulation of Earth’s environment by the combined activity of its living organisms causes the planetary system to behave in ways previously attributed only to individual living organisms, colonies, or ecosystems. Biological processes, tightly coupled with physical processes, control and stabilize global environmental conditions in ways that favor their perpetuation. Gaia theory, at the planetary scale, demonstrates the core notion of the theory of ecological succession, which is that life creates a better environment for life itself.

Geophysiology and Earth Systems Science

Gaia theory implies that if Earth is a single living system, then planetary science becomes a kind of global physiology (geophysiology) while global environmental management may be conceived as a kind of planetary medicine. It also suggests that the Earth system has a significant capacity to defend itself against a changing external environment. In this respect, it acts like a primitive living creature. When it becomes too warm, it cools itself down, and when it is too cold, it warms itself up. Gaia theorists have collected considerable supporting evidence, but their most powerful single argument involves global temperature.

The traditional scientific argument for the existence of life on Earth is that the planet is perfect for life. This is the so-called Goldilocks hypothesis: Venus is too hot, and Mars is too cold, but the Earth is just right. However, the sun is a star and has the same life cycle. In the past 3.8 billion yrs. (years) of life on Earth, its output has increased by less than 10%. This means that if conditions are just right for life now, they must have been very cold when life began, or if they were perfect when life began, it should be very hot now. However, Earth’s temperatures have remained remarkably constant. The oceans have
neither been so hot that they boiled away nor, in the past 0.5 billion yrs., so cold that the whole Earth froze. The reason is climate regulation by changing levels of atmospheric carbon dioxide (CO₂). Today, this gas makes up more than 98% of the atmospheres on Mars and Venus but only 0.03% of that of Earth. The missing atmosphere is found sequestered into rocks, such as the limestone rocks that cover an eighth of the planet’s land surface, and in all the other organic rocks and sedimentary layers. Most limestone rocks are constructed of small shells. It is life that has buried Earth’s excess CO₂.

Viewed as a whole, while the atmospheres of Mars and Venus are chemically stable, Earth’s atmosphere is not. Instead, it shows a statistically improbable combination of extreme chemical instability and long-term constancy. Many of the causes of the chemical instability, the amount of free oxygen and methane, are obvious by-products of life. Much of the constancy on Earth is also mitigated by life—biogeochemical recycling being the key. This is why Gaia theorists claim that it is impossible to understand the current physical state of air, the ocean, or Earth without recognizing its biological control. Biological processes keep the planet’s physical systems in their condition of dynamic equilibrium, a state that is ideal for life, which needs to process mobile materials, but which would be impossible on a dead planet.

**Daisyworld**

This gives rise to the question “How does all this occur?” The answer is indicated by Daisyworld, a simple yet powerful mathematical model that at once tames the nonlinear rules of population growth and demonstrates the way in which the tightly coupled feedback between biological and physical processes makes planetary self-regulation by the biosphere possible. Daisyworld is a simplified planet that exists in the mind of a computer. Its surface color is neutral gray, and it rotates in front of a star that, like ours, is getting steadily warmer. The planet is seeded with just two species of daisy, both of which thrive best at one temperature—perhaps 200 °C, which germinate at 150 °C and die at 250 °C. One species is light colored, the other dark colored. Light-colored daisies cool their local environment by reflecting the sun’s rays; dark-colored daisies absorb heat and warm up their locale.

In the model, as temperatures rise, eventually they pass the threshold for germination. At this time, black daisies, which warm their habitat, grow better, so they quickly cover the planet. As they do so, they raise its temperature toward the optimum. Above the optimum, light-colored daisies, which cool the environment, become more favored and begin to replace black daisies competitively, while collectively the two species combine to keep temperatures close to the optimum. Eventually, solar temperature increase means that only white daisies, which cool the environment, remain, and eventually, when they begin to die, the whole system collapses, and Daisyworld dies. Between the two extremes, however, the temperatures on Daisyworld remain remarkably constant. So here is the essence of a Gaia control system. There is no suggestion of conscious control; system regulation emerges as an inevitable consequence of the interactions between the organisms involved and their habitat. Since its creation, Daisyworld has developed its own large literature; there are also several computer models and a spreadsheet version freely available on the Internet.

**Gaia Debates**

The Gaia concept disturbs many people. One reason is that it considers very long timescales and a relationship between a huge planet (Gaia) (size: $12.76 \times 10^6 = 12,760,000$ m [meters]) and the main life forms that have inhabited the world through its existence, which are the unicellular bacteria of the microcosmos (size: $12.76 \times 10^{-6} = 0.00001276$ m, or much less for the dominant prokaryotic bacteria). Humans (size: $1–2 \times 10^{-1}$ m), while they may be impressive supercolonies of ca. $19 \times 10^9$ cells, exist between the two ruling scales of the Gaia system and across an infinitely small timescale (>0.001 billion yrs.). There is a fertile area of discussion about what, if any, might be the role or effect of humans on Gaia—for example, Are humans a planetary disease? Are they Gaia’s organs of reproduction? Will their impacts trigger Gaia’s shift to a new warmer system state? and many other speculations.
Given these considerations, it is not surprising that Gaia theory has its share of criticisms, many of them based on sound scientific arguments. Of course, the notion is also anathema to fundamentalists ranging from neo-Darwinists such as Richard Dawkins, to reductionist scientists, to the supporters of various, mainly Abrahamic, religious systems. Some of these problems arise because the Gaia hypothesis has been expressed in many ways. John Kirchner, a leading Gaia critic, recognized a spectrum of Gaian hypotheses running from weak to strong in the scientific literature. Table 1 covers the range of views that impinge on geographical inquiry. The last column tries to indicate the current measure of support each notion receives from the scientific community.

<table>
<thead>
<tr>
<th><strong>Eight Gaia Concepts</strong></th>
<th><strong>Different Conceptions of Gaia</strong></th>
<th><strong>Environment-Oriented Geographers Often Regard This View as</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metaphorical</td>
<td>Gaia is a metaphor for the unity of the Earth’s environmental system, especially the interlinkages of its biological components.</td>
<td>Romantic but apt and useful</td>
</tr>
<tr>
<td>Influential</td>
<td>The biota has a substantial influence over many physical geographical and Earth system processes.</td>
<td>Certain</td>
</tr>
<tr>
<td>Coevolutionary</td>
<td>The biota influences the physical environment, and this in turn influences the evolution of the biota by Darwinian processes.</td>
<td>Probable</td>
</tr>
<tr>
<td>Homeostatic</td>
<td>The interplay between biota and environment is characterized by self-stabilizing negative feedback loops (Daisyworld model).</td>
<td>Debatable but possible</td>
</tr>
<tr>
<td>Teleological</td>
<td>The atmosphere is kept in homeostasis, not just by the biosphere but in some sense “for” the biosphere.</td>
<td>Speculative</td>
</tr>
<tr>
<td>Optimizing</td>
<td>The biota manipulates its environment for the purpose of creating biologically favorable conditions for itself.</td>
<td>Improbable</td>
</tr>
<tr>
<td>Organismic</td>
<td>Gaia is a living organism composed of many species, much as higher organisms are composed of many cells, and like any organism, it seeks to preserve itself and to reproduce.</td>
<td>New Age</td>
</tr>
<tr>
<td>Religious</td>
<td>Gaia is an aspect of the Goddess or of God, who runs the Earth for Her or His own purposes.</td>
<td>Religion</td>
</tr>
</tbody>
</table>

Table 1  Eight conceptions of Gaia


Gaia Today

Gaia is an independent scientific theory of the living Earth. It is one of the most important ideas in modern physical geography, with a scientific core and an elegant mathematical base in Daisyworld. The concept is a logical consequence of the originally organicist, general-system thinking that was in vogue in physical geography for more than two decades in the late 20th century. The romantic and evocative adoption of the name of the goddess “Gaia” has increased both the popularity of the notion and the objections to it. Consequently, Gaia theory is most often taught under the more scientific-sounding strapline “Earth systems science.” Its creators and chief protagonists, James Lovelock, Lynn Margulis, and their followers, have shown how science can connect with the Gaia system, perhaps a superorganism. The Gaia concept is also fundamental to deep ecology and is widely used by environmentalists, especially ecofeminists, and the New Age Movement.

Martin J. Haigh

See also Climate Change; Deep Ecology Movements; Ecofeminism; Physical Geography, History of
Further Readings


Vasco da Gama was a Portuguese navigator and explorer and the first European who succeeded in reaching India after circumnavigating the African continent. He thus opened the way for new sea routes for trade and laid the foundations for the Portuguese Empire in Eastern Africa, India, and Indonesia, making his homeland for a period the main commercial leader in Europe.

At the time of da Gama’s voyages, spices and herbs had enormous importance, and their maritime trade was controlled by the Venetians, Arabs, Persians, and Ottoman Turks; on the other hand, their transport via land was very expensive. For this reason, powerful Western

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**Figure 1** Map showing Vasco da Gama’s voyage routes
*Source: Cambridge University Press.*
European nations aimed to find an alternative direction to reach Asia by sea. In 1497, King Manuel I of Portugal charged da Gama with an expedition. The navigator left Lisbon in July with four ships. He sailed past the Canary Islands and the archipelago of Cape Verde; then, trying to avoid the currents of the Gulf of Guinea, he crossed the equator. He got to Southern Africa in November, rounding the Cape of Good Hope, which had been previously reached by the Portuguese explorer Bartolomeu Dias in 1488. On Christmas day, 1488, he landed in what is now the province of Natal (in Portuguese, Natal means “Christmas”). After several more weeks of navigation, he arrived in Mozambique, where he had to stop because many members of the crew were affected by scurvy, an illness caused by lack of vitamin C, common among sailors who spent long periods on ships. When they finally got to Malindi, da Gama met the Arab expert navigator Ahmed bin Majid, who helped him reach Calicut, on the southwest coast of India, after a 1-month-long journey. His journey demonstrated that the Indian Ocean was not an enclosed sea, as imagined by ancient geographers such as Ptolemy. da Gama also provided interesting information about the Eastern African coast (its richness in freshwater and wood that was useful for repairing ships). However, in India, da Gama encountered hostile Arab merchants who tried to prevent trade with the local communities. da Gama used force to counter his opponents.

During his return journey, he faced unfavorable monsoon winds, and it took 5 months to get to the coast of Africa near Malindi. Once he reached Portugal in September, 1499, he was proclaimed the “Admiral of the Indian Seas” and, some years later, the Viceroy of India.

Susanna Servello

See also Colonialism; Exploration

Game Ranching

Game ranches are usually understood to mean an area of land, often enclosed by special fencing, where game animals are kept. There are many purposes for the existence of game ranches. Some owners of game ranches have no commercial motive and are purely interested in conservation and the private enjoyment of the experience of nature. Others acquire and breed animals to profit from live sales, hunting, or tourism. Financial reasons have made the latter type far more common, thus the for-profit type of game ranches is the focus of this entry.

The hunting aspect of game ranching often invokes negative connotations. Some species have become extinct through overhunting. Many people are sickened by reports of the “hunting” of sluggish, drugged lions. The use of dogs in the hunt is also controversial. Negative sentiments toward hunting have influenced impressions of game ranches. However, through hunting, the profitability of game ranches is enhanced. And it is the profit motive that leads to the sustainability and further establishment of game ranches and hence the conservation of wildlife. The rest of this entry addresses the situation in South Africa.

Game Ranching in South Africa

The trend toward transforming livestock production systems into game ranching increased rapidly from the 1990s. The Amalgamated Banks of South Africa estimated that by 2000 there were approximately 5,000 fenced game ranches covering an area of about 100,000 km² (square kilometers), representing a 10-fold increase since 1979. Thus, wildlife can now be found on game ranches that represent an area more than five times the size of the Kruger National Park. Despite the consumptive nature of the activities on most of these ranches, this is a considerable boost for conservation.

What triggered this growth in game ranches? Agricultural Control Boards in South Africa were deregulated, exposing the beef industry to competition from world markets. Consumer preference also shifted toward perceived healthier white meats and away from beef. Venison was also promoted as being low in cholesterol. The
1994 ending of apartheid opened up the potential for tourism, including foreign safari hunters. There was also an amendment in 1988 to the Share Block Control Act of 1980, which facilitated the acquisition of agricultural land for recreational conservation and game ranching.

The initial capital required to establish a game ranch is significant. In addition to the cost of land, capital is needed for infrastructure such as game fencing and tourist accommodation. Initial populations of game also have to be purchased. Not many people have access to sufficient funds for this purpose. The share block scheme, however, allows a coalition of individuals to pool their resources and acquire a game ranch.

**Management and Profitability**

It would appear that the rate of growth in the number of game ranches is driven mainly by the profit motive. There is some debate as to whether game ranching is more profitable than cattle ranching. Jacobus du P. Bothma and Wouter van Hoven reported a case in the Northern Cape Province where a game ranch yielded a net profit rate that was 7.3 times that of a cattle-only farm. They also reported a case in Zimbabwe where the net income from a 100-km² game ranch was 3.5 times higher than that from an adjacent 200-km² cattle farm. While some farmers are not convinced despite these examples, it seems that the profitability of game compared with cattle increases with aridity. The scientific management of game ranching in Africa is relatively new, and managing for profit is even more recent. *Game Ranch Management*, edited by Jacobus du P. Bothma, was the first significant volume devoted to this topic. The book covers a wide range of topics, such as veld (an elevated open grassland in Southern Africa) management, game capture and transportation, provision of water, buildings, airstrips, game species and their habitat requirements, and monitoring.

With an average game ranch size of about 2,000 ha (hectares), there are many game ranches where it is not viable to maintain a population of large predators such as lions. To prevent damage to the veld, surplus stock needs to be removed either through live sales or hunting. With an increasing emphasis on profits, the following question becomes important: How can the balance of species be distorted within ecological constraints so as to maximize returns? This question was addressed by John Hearne and colleagues for the Controlled Hunting Area of Mkuzi Game Reserve in Northern KwaZulu-Natal. The authors formulated a linear programming problem (LP) that optimally allocated browse, bulk graze, and concentrate graze to the various species in the area. Hence, the optimal population numbers of each species and the returns from their harvest were calculated. To minimize the large initial capital outlay required, further LP analysis was undertaken to determine an optimal transition plan to a fully functioning game ranch over a 5-yr. (year) period.

Sophisticated mathematical modeling research has continued in an effort to improve decision making for managers of game ranches. This research includes recognition of both the multi-objective nature of managing game ranches and the stochastic aspects of rainfall in determining optimal management strategies. In addition, the stochastic nature of prices and growth rates has been handled by using portfolio selection techniques to determine the optimal target populations for each species. In this approach, food resources are allocated to different species, depending on the returns and the variances and covariances of these returns. Most trophy hunting is marketed as a package. For example, a 7-day buffalo package might include some plains game species and a warthog in addition to a buffalo. For this problem, optimal marketable packages, and hence optimal population levels, for each species have been determined.

**Conclusion**

Game ranching offers an opportunity to turn marginal lands into profitable ones in Southern Africa. From very little documented knowledge about 40 yrs. ago, increasing scientific activity from fields as diverse as veterinary science and operations research should ensure enhanced profits and thus the use of even more marginal land for game ranching. Advocates of game ranching maintain that this strategy offers Southern Africa its best chance of conserving its priceless wildlife.

*John W. Hearne*
GATED COMMUNITY

A gated community is a specific form of residential development that is becoming increasingly widespread in many developed and some developing countries. In the most inclusive definitions, a gated community is described as a residential area surrounded by a wall or other means of enclosure, with access controlled at a gate. Specialists require two added criteria. The residential area must be governed by a local governing body, a community association, which is a contractual association responsible for ensuring adherence to regulations and for providing local civic goods and services and whose resources derive from fees paid by the residents. The gated community must also have amenities or infrastructures that are normally publicly owned and operated, such as a park or a street, but are in this case privately held and maintained.

There are different typologies of gated communities. Edward Blakely and Mary Gail Snyder define three main categories: (1) security zones—characterized by restricted access alone; (2) lifestyle communities—which offer amenities, most often recreational (tennis courts, golf clubs, etc.), as well as restricted access; and (3) prestige communities—which offer their elite membership the distinction of living in an especially desirable location.

There are various forms of gated communities in many widely differing countries such as the United States, China, South Africa, or Brazil. Gated communities are more often located in urban environments but also exist in rural areas (secondary residences). In urban settings, they are found in suburbs as well as in central cities and even inner cities, and in more recent and older neighborhoods. They may include single-family or semidetached homes, apartment buildings, or even residential towers (although many specialists clearly distinguish between gated communities and condominium towers). Their size may range from several dozen to several thousand homes. Their residents generally come from the middle or upper classes, but gated communities inhabited by low-income households also exist. Many retirement communities are adopting the model of the gated community, particularly in the United States.

The opinions on gated communities vary considerably. There are numerous debates on their impacts, more often seen as negative than positive, on local taxation and economies, on social cohesion, and on service provision, and the offer of local collective amenities. Initial analyses of the phenomenon in the 1990s mainly saw gated communities as a source of social segregation on the basis of income especially, because of their capacity to target particular clienteles due to the cost of the housing, the specialized offer of services and amenities, their internal regulations, and the high residents’ fees. The analyses also raised the notion of urban secession to describe this new residential form, not only because of the phenomena of enclosure and microgovernance that underlie it but also due to quite vigorous struggles on the part of residents of gated communities, especially in the United States, to obtain local tax reductions.

Supporters of privatization say that gated communities are more efficient in their offer of collective goods and services, which may differ in each gated community, so that households can choose and pay for only those services and amenities that

See also Hunting and Gathering; Landscape and Wildlife Conservation; Marginal Regions

Further Readings

they are likely to use. Some see gated communities as a way of re-creating neighborhood communities in increasingly diversified (and, in some cases, polarized) urban environments characterized by high residential mobility. This view is, however, contested due to the very constraining regulations found in some gated communities and the tendency for residents to launch legal proceedings when disputes arise, which have nothing in common with the modes of conflict resolution regarding lifestyles and the residential environment found in communities in the sociological sense of the term.

A number of factors—cultural, social, economic, and political—underlie the development of gated communities. One of these is people’s feeling of insecurity, whether well-founded or not, which has been largely exploited by promoters of gated communities. Residents, especially in big cities in developing countries, are said to be looking for a safe environment in these communities, where they are better protected from crimes against individuals or property. In societies that are becoming increasingly socially diverse and polarized, the fear of the Other, of difference, is also a factor: Many people now feel threatened in public spaces. In developing countries, where local administrations have few resources or capacities, gated communities are said to represent a way of ensuring reliable urban services and infrastructures, at reasonable cost, for wealthier inhabitants. In urban peripheries populated by impoverished households, gated communities are seen as enabling very socially and economically
diverse populations to live side by side. Another factor is undoubtedly the attraction for wealthy households of a type of housing and lifestyle in vogue in rich and developed countries such as the United States. In developed countries, promoters present gated communities as a means for middle-class residents to ensure a nonsaturated and efficient offer of specific services and amenities (e.g., recreational facilities) at a reasonable cost. Municipalities can also play an important part as, under certain conditions, gated communities may enable them to attract a solvent clientele without having to make large investments in infrastructures and services. Finally, buyers investing in property in gated communities may feel that they have an additional guarantee of security and profitability in such communities.

Many questions are raised by the study of specific gated communities in various countries due to the great variation in their forms and contexts. What impacts do gated communities have on the surrounding populations and territories? Is the emergence of gated communities enabling a minority to obtain good-quality services and amenities while leaving other inhabitants, particularly less well-off, highly vulnerable populations, in poorly served environments? Or, on the contrary, by developing services and amenities that their residents finance privately, are they allowing municipalities to devote more resources to the rest of the territory? When gated communities are set up, do property values outside these communities rise or fall? Do gated communities in very impoverished areas in large cities in developing countries represent a source of jobs for the highly vulnerable populations around them? Are the barriers established by gated communities significantly affecting the flow of pedestrian and vehicular traffic, and under what conditions? Why are gated communities very popular in some countries and much less so in others?

The realm of gated communities requires a great deal of further study, as there are as yet few definitive answers to these questions. What is known is that in the different contexts in which gated communities exist, there is a wide range of forms, factors, and impacts.

Anne-Marie Séguin

See also Ethnic Segregation; Gentrification; Housing and Housing Markets; Racial Segregation; Segregation and Geography; Social Geography; Urban Geography

Further Readings

Gays and lesbians (but mostly gay men) began appearing regularly in Anglophonic geography in the 1970s. A few brave geographers—including Barbara Weightman, Bob McNee, E. M. Ettore, Jacquelyn Beyer, and Bill Ketteringham—wrote and presented papers that sought modestly to document gay spaces and the impacts of gay people on (mostly urban) landscapes. These early works tended to be isolated and marginalized within the discipline. Meanwhile, more theoretically ambitious work was going on in sociology, anthropology, history, and other social sciences and humanities. One particularly important contribution, published in the early 1980s, was by the famous sociologist Manuel Castells. Along with his graduate students Don Lee and Karen Murphy, Castells mapped and interpreted the development over time of a spatially concentrated gay community in San Francisco. Castells’s analysis linked gay community development and political empowerment to spatial concentration and situated its conclusions within a larger theory of urban politics informed by case studies from around the world over several centuries. In addition to taking space seriously, Castells’s work posited significant differences between gay
male and lesbian cultures and communities and suggested plausible reasons for these differences.

With the emergence of feminist geography in the 1980s, the shift from gender to sexuality was not much of a leap. Since then, gays and lesbians have become more visible in the discipline (and society at large), both as practitioners and as interesting, and understudied, “objects” of inquiry. A 1995 collection called *Mapping Desire*, edited by David Bell and Gill Valentine, was the first volume to focus specifically on geographies of sexualities, and it concentrated largely on gays and lesbians. Areas of geographic interest then expanded to include, inter alia, the relationship between gay communities and gentrification, the differences between gay male and lesbian lives and communities, rural gays and lesbians, geographies of bisexuality, and intersections between geographies of sexuality, race, and class. By the end of the 1990s, a wide range of traditional geographic preoccupations (e.g., cultural and political geographies, migration studies, medical geographies, travel and tourism) were being regularly reconsidered and reconfigured, at least in part, in light of issues pertaining to gays, lesbians, and other sexual and gender minorities. Furthermore, gay and lesbian geographers were attempting to negotiate new theoretical developments in geography, such as postmodernism and poststructuralism. This turn led to analyses that considered homophobia and heterosexism as part and parcel of larger structures of oppression, including classism, patriarchy, and racism. Concomitantly, the new awareness of gays, lesbians, and broader issues of gender and sexuality led to the emergence of new empirical areas of geographic inquiry, including those surrounding HIV/AIDS, notions such as “closeting,” new forms of popular culture, and “postmodern” social movements (e.g., the “queer” and anti-identitarian political movements).

Indeed, many of geography’s most important theoretical developments over the past two to three decades are inseparable from the more quotidian achievements of gay and lesbian geographies and geographers (as well as others whose lives and experiences have become visible in a post-Fordist, neoliberal, globalized world, such as women, people of color, immigrants/refugees, and postcolonial subjects). In particular, engagements with feminist, postmodern, poststructural, but especially what has come to be known as “queer” theory have fundamentally transformed both gay and lesbian geographies as well as much of the discipline’s “mainstream.” These perspectives tend to include skepticism about grand theories and reductionism of any kind, along with a distrust of many, if not most, of the established hierarchies of power. Queer theory’s particular lens foregrounds issues of sexuality and desire—especially nondominant and transgressive forms of sexuality and desire—and applies its disrupting insights from this exercise to other domains of geography. The result has been the emergence of new, more sexually sensitive geographies of economy, culture, politics, and the environment.

With respect to gays and lesbians in particular, the focus has shifted away from issues of identity and spatially defined “communities” to fractured and hybridized “subjectivities” whose spatial forms are fluid, always in formation, and enmeshed with similarly fluid and incomplete geographies of race, class, gender, ethnicity, and other forms of difference. In this context, it sometimes becomes difficult to distinguish gay and lesbian geographies (or geographies of gays and lesbians) as something distinct. Still, such geographies continue to be produced, albeit more often under the rubric of “queer” than “gay and lesbian.” Even so, there are recurring debates within queer geography about whether or not the work being produced is “queer enough” (i.e., sufficiently anti-identitarian and intersectional), as well as recurrent, perhaps ironic, debates around whether or not there is enough attention paid to sex and sexual relations per se. Some of the more recent work in queer geography concerns the politics and practice of “seeing” gays and lesbians in government-produced (and other) statistics, the diffusion of queer cultures and politics globally, the connections between sexuality and health geographies, and a wide range of issues lying at the intersections between gender and sexuality (e.g., drag, transgenderism, queer masculinities/femininities, and queer sexisms).

So geographies of and by gays and lesbians have evolved quite substantially over a relatively short period of time. These works continue to grow and
diversify, with attempts to accommodate ever newer theoretical and empirical developments (e.g., actor-network and nonrepresentational theory; the mainstreaming of gays and lesbians through institutions and practices such as marriage, child and elder care, and homemaking). Indeed, it would not be surprising to see this growth and diversification spawn an entirely new set of critiques grounded in a sense of loss of, and nostalgia for, the days when “gay” and “lesbian” were understood as intrinsically radical, and radically distinct, categories.

Lawrence Knopp

See also Feminist Geographies; Identity, Geography and; Masculinities and Geography; Poststructuralism; Queer Theory; Sexuality, Geography and/of

Further Readings


Historically, gazetteers served as indexes to place names on map sheets or maps in atlases. A person could look up a place name in the gazetteer and get a page or map sheet number along with a grid reference (e.g., E4) and be able to find it on a map. The gazetteer thus served an important role in information retrieval. In its digital incarnation, a gazetteer serves a similar role as an aid for information retrieval.

One of the most widely used and known gazetteers in the United States is the Geographic Names Information System (GNIS). This digital gazetteer is maintained by the U.S. Geological Survey along with the U.S. Board on Geographic Names. As of December 21, 2009, there were 2,123,538 entries in GNIS covering more than 60 different feature classes. An entry in this gazetteer includes an official place or feature name; alternate feature names; the feature class; the state and county where it is located; the name of a topographic map on which the feature occurs; its latitude, longitude, and elevation; and an entry date.

Recently, the International Organization for Standardization (ISO) 19112 and the Open Geospatial Consortium defined content standards for digital gazetteers and interoperable gazetteer services such that gazetteer services can be executed over the Web. Standard contents for a gazetteer include an official place name; alternate names, including historical or multilingual names; a feature type; and a spatial position most often specified as a point with two-dimensional (2D) or 3D coordinates.

In their digital form, gazetteers are extremely useful for a range of geospatial search functions. Their value lies in their ability to translate between different location representation systems. Locations can be represented textually by place names and addresses or numerically by 2D or 3D coordinates in different spatial reference systems. A person can thus query a gazetteer with a coordinate range and retrieve place names contained within that range. Alternately, a person can query the gazetteer with a place name and retrieve a coordinate location or description for the place name. Location-based services may employ gazetteers to translate a person’s coordinate location obtained
by global positioning systems to an address location or to return nearby place names or features of interest. Geospatial information on the Web may have many different location reference forms, so comprehensive searches of the Web for geospatial information will rely more and more on gazetteers to serve as the translators between these diverse reference forms. Suppose a person searches for water-quality data on Sebago Lake. Such data may be referenced using spatial coordinates, or place names, including place names with misspellings. The gazetteer can be used to expand the search from the place name the user enters to alternate names and coordinate descriptions such that the user has a greater chance of finding all the pertinent information.

Gazetteers can also serve as the geographic knowledge source to support automated text processing, spatial grounding of text descriptions, data mining, and information integration. For example, by processing a news article using a gazetteer, one could translate any place name references to coordinate references, plot these on maps, and compare these with place locations in other new articles and with other information sources.

Kate Beard-Tisdale

See also Place Names; Toponymy

Further Readings


GENDER AND ENVIRONMENTAL HAZARDS

The human experience of environmental hazards is not only determined by forces in nature but also is contingent on social, political, economic, and cultural processes. An emergent literature in the hazards field emphasizes the concept of vulnerability, thereby drawing attention away from the “naturalness” of environmental hazards and toward the underlying reasons for the differences in exposure or impact that exist geographically. This work takes seriously several characteristics that mediate the vulnerability of individuals, households, and groups to risks and hazards. One important, yet relatively neglected, socially constructed characteristic influencing vulnerability to environmental hazards is gender. Gender interacts with age, class, caste, ethnicity, religion, economic position, and other underlying social processes to affect the conditions that influence exposure to hazardous situations in the environment. Gender is also a factor in governing the capacity of individuals or groups to respond to and cope with hazards’ harmful and damaging effects. As such, the intersections between gender and other social categories and distinctions need investigation and analysis.

New insights have emerged from research that employs gender as an analytical category in the study of environmental risks and hazards. On a conceptual level, several major gender dimensions have been highlighted. There are some biological and physiological differences between women and men that at times influence their exposure, susceptibility, and response to environmental hazards and their impact. The vulnerability of men and women is influenced by where they are in their respective life courses. Pregnant women and lactating mothers are examples of particularly vulnerable social groups. Moreover, the disproportionate impact of environmental hazards on either women or men is not simply an outcome of biophysiological differences and varying physical exposures; it is an effect of vulnerability as determined by prevailing ideologies of femininity and masculinity that are reinforced through the social construction of gender roles, responsibilities, obligations, and opportunities. Social norms and roles of behavior and responsibility often place either women or men at greater risk from environmental hazards. Recent studies confirm that women generally suffer differential exposure to several serious hazards—fire used for cooking, indoor air pollution, toxic cleaning supplies, water contamination, and seismic activity that can destroy poorly constructed
dwellings—owing largely to the gender division of labor and space at the household scale. These divisions are the outcomes of the micropolitics of power at the household and community scales as well as wider social processes and structural inequalities. On the other hand, men dominate environmentally hazardous and dangerous occupations such as commercial fishing and logging, offshore oil drilling, and underground coal and mineral mining. Some exceptions exist to these patterns, depending on the type of environmental hazard, when gender roles may not affect women or men more adversely. Nevertheless, documentation from many places around the world suggests that gender vulnerability to environmental hazards is to a large extent the product of existing gender-based relations and/or inequalities.

Another point in this regard is that prevailing gender norms can influence perceptions of hazards in addition to access to resources, education, information, skills, training, and employment. Hence, there are long-term consequences for individual and community efforts to mitigate hazardous situations and to create safer environments. These gender dimensions are not mutually exclusive but necessarily reinforce each other.

The issues underlying the relationship between gender and environmental hazards are complex. Gender vulnerability must be considered within the context of the physical environment, social structures, and the local-global interactions of pressure-applying forces. In areas where women and/or men are disempowered within the context of modernization theory, live in highly patriarchal or hierarchical social systems, or occupy dangerous built environments, they are more likely to suffer disproportionately in hazardous situations. Internal factors such as political disenfranchisement, poverty, access to education and services, and the outmigration of able-bodied men shape the social fabric of communities and the ability to exercise resiliency in coping with environmental hazards. The combination of these factors makes the everyday roles of social production and reproduction (e.g., growing crops, caring for their children, collecting water, gathering firewood, repairing homes) incredibly demanding for women, who make up a large percentage of the poorest of the poor. Other contributing causes of gender vulnerability include externally driven forces: large infrastructure projects such as dams and reservoirs, the expansion of industrial agriculture, forest clearing through commercial or illegal logging, mining and mineral extraction, and acts of aggression, war, and displacement. Commerce, construction, urbanization, structural adjustment policies, economic crises, and an eroding resource base have proceeded with little regard to environmental risks and hazards, whereby social and environmental marginalization along gender lines in some places has increased.

It is well documented that women in much of the world bear the primary responsibility of managing the household environment. On account of their sociospatial location, they may be confronted with an entirely different array of environmental deficiencies and risks than men. Urban and rural services and amenities that are deteriorating or nonexistent result in the accumulation of garbage, open defecation, fecal contamination, pest and insect vector habitats, and environmental health risks that pose threats to women, who serve as the principal environmental risk managers, especially in impoverished communities in developing countries. Socioeconomic status, age, and divisions of labor serve as important conditioning factors that render some women more vulnerable to impacts of household-level environmental hazards than others. Water and public health infrastructure and amenities are critical to reducing risk and mitigating the environmental hazards faced by low-income women and their families.

Some researchers suggest that in many places in the world the context within which gender relations are defined is changing, with implications for hazard response and coping. Studies have pointed out the ways in which women and men are attempting to address the multiple and interconnected issues of poverty, underdevelopment, environmental degradation, and hazard through strategies that have the potential to encourage gender equality and tackle other gender-related challenges. Services or amenities supported by the state, such as water infrastructure and environmental rehabilitation, have the potential for improvement of the local environment, health, and economic well-being of the population and for risk reduction. In recognizing the importance of differences based on gender, governments stand to
gain key allies in their efforts to prepare for, mitigate, and respond to the risks and potential devastation associated with environmental hazards.

Sarah J. Halvorson

See also Environment and Development; Feminist Environmentalism; Feminist Environmentalist Geographies; Feminist Political Ecology; Gender and Nature; Political Ecology; Vulnerability, Risk, and Hazards

Further Readings


Gender and Geography

The geographical analysis of gender, or simply gender geography, has experienced significant growth since its origins in the 1970s. This field of study has developed from early research on spatial patterns of women’s activities to more recent analyses of how spatial processes are linked to gender identities and feminist methodology. Gender and other social relations have been incorporated into nearly all areas of the discipline and brought feminist perspectives to issues such as urban planning, globalization, and, more recently, geographic information science (GIScience).

Gender geography seeks to analyze how gendered social processes are linked to space, place, and scale. In this discussion, gender is defined as a social construct mediated by various axes of power that include race, class, ethnicity, and sexuality. The social construction of gender has often been compared with sex, which refers to the biological differences between men and women. Geographic analyses of gender underscore how this and other social categories are manifest differently across space and are instrumental in shaping the physical and built environment. Moreover, gender is associated with power relations and access to resources that affect mobility patterns such as commuting and migration as well as divisions of labor in the household and workplace. Feminist geography, a term that is increasingly used in connection with gender geography, also entails elements of praxis or engagement with research in a way that incorporates political action and practice. By exposing social and economic inequalities in the workplace, households, and other areas of society, for example, feminist geography has sought to challenge oppressive forces and provide alternatives that include incorporating women’s and gender issues in research projects and advocating for social change that empowers marginalized people. In sum, gender geography has expanded the horizons of geographic inquiry to explore alternative perspectives on spatial dynamics, social processes, and power relations.

Evolution of Gender Geography

Early scholarship in gender and feminist geography provided an important critique of traditional assumptions concerning gender roles and the unequal status of men and women in society. Starting in the mid to late 1970s, studies examined how gendered space affects women’s employment, commuting, daily time-space patterns, and other common geographical themes. This early work focused on the differences between men and women as explained by gender roles and relations. For example, gender roles profoundly affect labor market participation and commuting patterns for women as they tend to have greater responsibility for household and caretaking tasks. Consequently, limited employment opportunities affect their ability to hold well-paying, full-time, and more secure jobs.

Studies such as these raised a series of questions that launched both theoretical and empirical research on the intersections of gender and geography. One of these projects developed out of Marxist geography, which is based on critical
inquiry of class, capitalism, and uneven development. Radical and socialist feminists have engaged in debates about the relationship between capitalism and patriarchy as separate or interrelated systems. Drawing from this Marxist perspective, feminist geographers such as Jo Foord and Nicky Gregson argued from a realist perspective that gender relations between men and women are built on the necessary conditions of biological reproduction. This position was criticized as ignoring how capitalism affects gender relations. Other dimensions of Marxist feminism developed alongside Walby’s *Theorizing Patriarchy*, whereby patriarchal relations are seen as linked to structures in advanced industrial societies that contribute to inequalities between men and women. Examples of these structures include men’s exploitation of women’s unpaid household labor, segregation in the workplace, and state policies that privilege men. Overall, the issues raised by Marxist and other socialist feminists in geography expanded the scope of and infused gender perspectives into the discipline.

Additional contributions of gender geography in these early decades involved international research on the status of women in countries throughout the world. This research includes empirical analyses of migration, urban planning, and rural development issues. Detailed case studies and maps comparing urban and rural areas, the First and Third Worlds, and regional socioeconomic conditions drew attention to the spatial patterns of gender relations and the status of women. Women’s employment activities vary widely throughout the world (data provided in Table 1). This representation of women’s involvement in the formal economy raises important questions about scale, accuracy of aggregate data, and alternative measures of economic activity.

The unequal status of women in the discipline through the late 1980s partially explained the lack of attention to gender issues in mainstream geographic research. In a landmark article published in the early 1980s, Janice Monk and Susan Hanson took the discipline to task for failing to consider “half of the human in human geography” and for its masculinist base. This omission was partially explained by the underrepresentation of women among faculty and students in the discipline and the subsequent lack of research on women’s and gender issues. Monk and Hanson and other feminist geographers argued that increasing the number of women in the discipline is bound to improve the amount and quality of scholarship on gender and geography.

Early efforts to address the omission of gender-based research were grounded in analyses of urban and economic geography. A central theme in this literature was the spatial and social separation of home and waged work, which associated the private sphere with women and the public arena with men. Gender-based research contributed to these analyses of the spatial patterns of urban space from early industrial to postmodern cities. The division of public and private space in urban areas provides an interesting comparison of different cultural contexts. In Islamic cities, for example, women’s mobility and presence in public spaces are more restricted than in Western ones. Recent feminist analyses of gendered spaces in the city and at work also challenge the social and spatial binaries of paid labor in the workplace and domestic labor in the home. Home-based work, for example, is an important income-generating strategy for many women and thus merges the productive and reproductive spheres. These and other alternative economic practices destabilize mainstream views of the sociospatial separation of home and work.

**Social Difference and Gender Geography**

The late 1970s and early 1980s marked an important shift in the approach of gender geography in response to critiques about its exclusion of non-Western perspectives and the dominance of white, Western, and middle-class biases in feminist studies as a whole. Third World and non-Western feminism challenged Western feminism to include other social categories such as race, ethnicity, age, and sexuality. Additionally, rather than situating these categories merely as empirical measures, feminist scholars writing about the global South and race were urged to examine the complex intersection of multiple social identities that contributed to discrimination and inequality. Researchers also questioned the “naturalization” of these
## Table 1

Percentage of economically active females, ages 15–19, 2005

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<th>Country/Region</th>
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categories in geographical realms of the landscape, everyday language, and spatial practices. Additionally, other aspects of social difference were incorporated into empirical studies about the journey to work for African American and Latina women, women’s experiences throughout the life course, and the performance of sexual identities in place. This research was strongly influenced by poststructural approaches that question the notion of a unified subject and explore the limits of hegemonic discourse. Poststructural theory uses the method of deconstruction to destabilize the hierarchical and oppositional categories that form the basis of Western rational scientific thought. Poststructural feminism has contributed to this field of inquiry by deconstructing the dichotomous categories of male/female, culture/nature, and productive/reproductive labor. Likewise, feminist geography helped advance nonessentializing critiques of the construction of gender and space.

The application of poststructural feminism in geography has been strengthened by the work of J. K. Gibson-Graham’s feminist critique of political economy. This groundbreaking research examines how capitalism is part of a hegemonic discourse that has marginalized other noncapitalist forms of economic activity. For example, barter activities and other nonmarket forms of exchange are valid and often sustainable practices in many household and community economies. According to Gibson-Graham, these alternative economic activities open up spaces of resistance in the context of hegemonic capitalist oppression.

Postmodern feminism also created opportunities to critique essentialist views of society and dominant notions of objective truth. In particular, postmodernism’s rejection of totalizing views of the world and of progress associated with modernity is consistent with feminism’s critique of hegemonic theory and practice. Certain feminists, however, object to postmodernism’s refusal to ground critique in the solid foundation of uneven power relations, especially those power relations embedded in oppressive patriarchal structures. In contrast, feminist perspectives on the diversity of representation and truths subscribe to an antiesSENTIALIST position where gendered identities are fluid, contested, and negotiated.

Since the early 1990s, efforts to broaden critical perspectives in gender geography drew from postcolonial feminism. According to this approach, regions in the global South once dominated by mostly European colonial powers remain influenced by relations and discourses of powers that stem from Western forms of thinking and politics. For example, the political systems, economic transactions, and cultural practices such as language and religion in many parts of the global South reflect the legacy of European colonization. Under colonialism, these dominant power relations often suppressed local, indigenous forms of knowledge and social relations, including those that affected the status and roles of women. Postcolonial feminism analyzes how patriarchy was shaped by and affected colonial politics and social identities surrounding gender. In many colonial societies, women were placed in submissive positions or not given access to land or property rights under European-ruled administrations. This approach also explores the role of white women who participated in the colonial project as travelers, military personnel, and writers. Journals and travel logs by colonizing women are often diminutive of colonialized women in ways that dwell on racial and other discourses of difference. Postcolonial feminism thus disrupts the dichotomies of colonizer/colonized and male/female by recognizing the shifting positions of the subject.

Part of the postcolonial project also entails acts of resistance that challenged the colonial system and questions Western feminism. Subversive interactions between colonizers and the colonized transformed the nature of this unequal power relation and in some instances empowered the colonized to assert their autonomy or gain certain rights. Building on this strategic resistance, some women in the global South have critiqued the idea of feminism as inappropriate for their experiences and perspectives. “Womanism” provided an alternative approach that captures the politics of women’s interests and experiences in the global South. Within this approach, issues concerning motherhood and matriarchy have a unique and distinct meaning in many of these societies based on cultural and material practices.
Gendered Transnational Migration

More recent contributions of feminist geography’s work on globalization address transnational migration. In this framework, both permanent and temporary migration patterns are affected by gender roles and identities. For example, migrant women take on different roles from men based on the intersection of gender relations in their countries of origin and in the host countries. Studies demonstrate that ties to both places remain important aspects of their livelihoods, social networks, and political organizing. For example, in parts of Asia, women may be more constrained due to restricted mobility, while they are free to travel and commute to work in a European host country. The identities of immigrant women are thus connected to the dominant (host) culture yet complicated by the values and gender relations in their own culture.

Likewise, issues of citizenship and subsequent rights to work and live are restricted for immigrants in many industrialized countries. Thus, concepts such as social and political boundaries, mobility, and production of space raise important questions for feminist researchers studying transnational migration. Feminist studies on the exploitation of women as domestic servants and sex workers, for example, describe the prevalence of often oppressive situations and the basic violation of human rights experienced by these women. Geraldine Pratt’s work on Filipina migrants in Vancouver, Canada, explores how these immigrant women’s bodies are constructed through their positions as caregivers and, in some cases, undocumented workers. Feminist geographer Melissa Wright also analyzes the violence directed at migrant women in her research on workers in Mexico’s maquiladoras. Their representation as cheap and docile has contributed to official reactions that minimize the high rates of murder and rape of factory workers in these areas.

Gendered Bodies

The embodiment of power and social identity extends to other areas of gender geography. In this area of research, the scale of the body provides a space or context to explore not only social identity but also spaces of resistance and empowerment. Performance of these social identities takes place in the body through dress, behavior, and other forms of social expression. Judith Butler’s work on gender and performance has been followed up by many feminist geographers who refer to the body as actively involved in the production of subjectivity. Thus, the body is not merely a biological entity but a product of a particular social and cultural context. Michel Foucault expanded this work by theorizing the body as a point of inscription where discourses are represented. From a gender perspective, scholars examine how bodies are marked as male and female through practices and lifestyles such as makeup, physical exercise, and posture.

The field of queer theory and geographic research on sexuality and space has greatly expanded this conceptualization of the body and social representation. In particular, geographical analyses of queer studies approach the body as a site of resistance in efforts to destabilize the dichotomy of a heterogeneous norm. Gay, lesbian, bisexual, and transgender identities and spaces represent important alternatives to heterosexual relations, challenging the dualisms that construct masculinity and femininity as dominant social relations. Research on sexuality and space has addressed a broad range of issues concerning urban politics, gay and lesbian activism, representation and identity, and time-space studies. This field also employs deconstructivist methods of analysis that represent a transgression of heteronormative relations and binaries that oppress nonheterosexual people.

Methodology

The theoretical frameworks and empirical studies discussed above are influenced by methodological approaches in gender geography. These approaches incorporate feminist perspectives in the research process, exploring the positionality of researchers and research subjects, as well as critically reflecting on “the field” as a place of research. Through strategic selection of research topics and emphasis on certain methods of inquiry, feminist geography critiques positivist research for its claim that research can be objective, value-free, and unbiased. In contrast, gender geography recognizes that research is a subjective process that entails biases concerning
the questions asked, conceptual approaches, and methods of analysis.

Feminist methodology also challenges unequal power relations in the research process by destabilizing the relationship between the researcher as “expert” and the participant as informant. These dynamics are considered exploitative and hierarchical by feminist scholars. Debates within the field of gender geography have also raised interesting issues about the use of quantitative and qualitative methods. Some scholars pose questions about whether or not one can “count” or quantitatively analyze issues pertaining to gender relations and feminist inquiry.

Finally, feminist methodology uncovers important dynamics and relations concerning spatial and social processes through a variety of methods such as interviews, focus groups, visual analyses, and participant observation. These methods often empower and provide a voice for the subjects of research and other marginalized voices. Innovative approaches have been used in feminist geography to implement the possibilities of resisting dominant, hierarchical dynamics in the research process. Among these are methods that allow researchers to work with individuals and groups in marginalized communities. For example, using ethnographic methods, Richa Nagar and her collaborators in rural India have conducted activist work with nongovernmental organizations on rural development. This research raises questions about personal identities and the sociopolitical positionality of the institutions in which they are situated. In addition, Nina Laurie works with communities in South America on gender and livelihoods. Her research questions the unequal dynamics often presented in projects in the global South that involve academic researchers from the West. Thus, feminist methodology is an important component of feminist geography in its role of challenging hegemonic assumptions about the research process, providing alternative means of gathering and analyzing data, and incorporating activist or agendas in research.

Many of the themes in feminist methodology highlighted above have affected how feminist geography has contributed to GIScience. For example, work in critical GIScience incorporates social issues of power in the design and implementation of this technology as well as in how data are analyzed. Likewise, feminist perspectives demonstrate how users of GIScience technology and its applications have been affected by social identity such as gender and particular subjectivities or biases in the research process. Mei Po Kwan and other feminist researchers in this field argue that GIScience can be used to deconstruct binary analyses and construct critical perspectives on sociospatial processes. Recent feminist scholars call for GIScience to be practiced in a more reflexive manner, opening up discursive spaces for alternative visions of the technology and its applications.

Examples of innovative feminist GIScience include Sara McLafferty’s work on breast cancer in Long Island. This project involved cancer victims, policymakers, public health officials, and GIScience practitioners, who developed extensive maps and data in an attempt to reveal causal factors. Although challenges arose, the project was an attempt to empower women and communities affected by the disease with information and regulation of possible environmental hazards. Another example of feminist GIScience research is Kwan’s work on time-space geographies of women in the urban areas of Portland, Oregon, and Columbus, Ohio. She documents the mobility patterns among women of different ethnicities as they undertake employment activities, household responsibilities, and nonemployment travel. Some of this work involves innovative GIScience techniques such as three-dimensional visualization.

The Future of Gender Geography

In sum, gender geography has developed tremendously since its early focus on women’s activity patterns. The growth in this field has borrowed from and contributed to critical analysis of the gendered processes that affect the spatial dimensions of political, economic, and social change. Future directions of research in gender and geography will bring continuing attention to diversity and alternative identities as essential elements in sociospatial processes. An important component of this work will be to continue to explore the intersection of various scales from the body to the global arena. Additionally, the recent growth in feminism and GIScience promises to develop further as gendered perspectives and methods enhance geospatial technologies. Finally,
emphasis on activism and social change will lead to growth in the relevance and progressive impact of research in gender geography. This research will in turn strengthen efforts that challenge hegemonic and oppressive tendencies across cultural and political boundaries.

Ann M. Oberhauser

See also Body, Geography of; Feminist Environmental Geographies; Feminist Environmentalism; Feminist Geographies; Feminist Methodologies; Feminist Political Ecology; Gays and Lesbians, Geography and/or; Gender and Nature; Identity, Geography and; Masculinities and Geography; Sexuality, Geography and/or

Further Readings


Gender and nature are two of the most powerful concepts through which our understandings of the world are shaped. They are central to the framework of meanings through which people tend to view themselves and (human and nonhuman) others. Mutually reinforcing, conceptions of gender and nature are inextricably intertwined. Geographers’ interest in these two concepts has been driven by an interest in exploring these connections and, perhaps more important, by efforts to destabilize the assumed nature-given categories of man, woman, and nature.

The term gender, as used in contemporary social theory, emerged as part of this denaturalizing impulse. Gender is generally understood to be a social category that can be distinguished from the biological (or nature-given) category of sex. Thus, early feminist theorists delineated gender as a system of meaning that objectifies women, rendering them passive, immobile, and closer to nature. Men in contrast are constructed as agents. Through their gradual subordination of nature, men have been portrayed as on the side of civilization, their historic role being to free humanity from its natural constraints. This system of meaning naturalizes patriarchy through a particular understanding of nature: It places transformative energies in the hands of men as master subjects. In contrast, recognizing gender as a social category suggests that it is open to change. Put at its simplest, even if I am a man, I do not have to act in masculine ways. As this example shows, sex is generally viewed as inescapable: Nevertheless, in recent years, the sex/gender distinction has itself been called into question. This division, it is argued, is a mirror of one of geography’s most deeply engrained binaries, the distinction between nature and culture. Within this system of meaning, nature has been framed as the essence of something: It is immutable and historically constant, as opposed to culture, which is viewed as a product of civilization. Questioning the reliance of the sex/gender distinction on both hetero-normative assumptions and dubious dualisms, feminist theorists have sought to historicize and contextualize sex in the same way as gender, showing it to be as much a social construction as the latter. In many respects, this echoes much of the work within critical studies of nature in which long-standing assumptions about the essential characteristics of nature have been progressively undermined. It also builds on a shift from epistemological to ontological questions. Sex, it is argued, is produced, constructed, and performed in ways not dissimilar to nature.
Although most of the work reviewed below still relies on a sex/gender distinction, this comes to be questioned in a variety of ways. This entry begins by discussing ecofeminism as a body of work that has placed gender-nature relations at the heart of its work. Then, the entry moves on to a brief consideration of feminist political ecology’s contributions before looking at the influence of a broader set of debates within cultural and historical geography. The final section explores the ontological politics in recent moves to question both sex and nature.

### Ecofeminism

Within environmental politics, the body of work that has done the most to explore the mutually constitutive relations between gender and nature is probably that on ecofeminism. This work has been driven by an understanding that patriarchy seeks to dominate both women and nature; women suffer the greatest from environmental degradation; and women are at the forefront of efforts to seek better environments. For some, this implied that a feminine conception of nature should be at the heart of struggles for a more appropriate ecological future in opposition to the dominant male-biased frameworks through which environmental conflicts are conventionally understood. Rather than rejecting the association of women with nature, biological and spiritual ecofeminists suggest that there is much of value in this relationship. Indeed, the masculinist domination of nature is contrasted with the deeper immersion of women in the rhythms of nature and the more authentic connections this permits.

Such work has been criticized for its static, singular conception of what it means to be a woman, its inability to contextualize nature as a construct or a product, and its romanticization of the struggles and lives of those in the global South (within much work, the Third World woman is a key figure for the salvation of humanity and nature). Nevertheless, social ecofeminists have begun from a similar starting point, developing a less naturalistic foundation through which the relations between women and nature might be conceptualized. At the heart of such work is the gendered division of labor. For feminist historical materialists—a key influence on certain conceptions of social ecofeminism—women’s work in capitalist patriarchy (cooking, cleaning, bringing up children) mediates the metabolic relation between humans and nature. Nevertheless, this relationship is a historically and geographically specific one that is open to change. Indeed, if the work of social ecofeminists ever proposes a more “feminine” engagement with nature, it is based on a more democratic division of reproductive labor between the sexes. Femininity, in turn, is recognized to be a social construction and not a quality inhering in one sex or the other. While less essentialist than biological ecofeminism, such an approach has still been criticized for implying too sharp a division between the spheres of production and reproduction, for not recognizing the differences among women, and, once again, for romanticizing the tough conditions in which women’s environmental knowledge is formulated.

### Feminist Political Ecology

While influenced by ecofeminist arguments, geographers’ main contribution to gender/nature debates within the field of environmental politics has been through work on feminist political ecology. Once again, the term captures a diverse range of approaches. At the core of work in feminist political ecology is an understanding of the “politicized environment.” This politicized environment is both produced out of and serves to reinforce the system of meanings comprising gender. Again, this work has focused on the day-to-day activities of men and women, the gendered division of labor that structures these everyday activities, and the ways in which such work transforms, modifies, degrades, or improves particular environments. Much of the focus of such work has again been on the global South, perhaps because of the apparent directness of the people’s engagements with the environments of which they are a part, although there has been an attempt to bring such work into closer conversation with struggles for environmental justice in the global North. Such work has focused more on the discursive ways in which women are understood to be closer to nature. The argument here is that it would be impossible to understand men, women, and nature (or their relationships to one another)
outside any such systems of meanings. Such work has shaped, informed, and transformed work on the social construction of nature.

**Landscape and the Masculine Gaze**

Within cultural and historical geography, feminists have focused on the dualistic frameworks through which geographical knowledge is produced within and outside the formal discipline. Geographical knowledge, it is argued, depends on the key binaries: nature/culture and feminine/masculine. A particular reading of the relationship between humans and their natural environments emerges because of these dualisms. Geographical knowledge has thereby been subjected to a symptomatic reading: Its silences, absences, assumed dualisms, and hidden assumptions are thereby subjected to much closer scrutiny. Here, some have turned their attention to the heroic figure of the male explorer, demonstrating the manner in which, from the very beginnings of the discipline, a particular relationship between a feminized landscape and a masculine producer of knowledge shaped geographers’ approaches to their subject.

In questioning the masculine bias to knowledge production, feminist historical geographers have sought to recover the important contributions of women travelers. Their written accounts are important examples of situated knowledge production about human-environment relations in a variety of historical and geographical contexts. Because of their exclusion from most histories of the discipline, focusing on these writings helps unsettle some of the dualisms through which geographical knowledge has been constructed.

Engaging more closely with visual methodologies, feminist geographers have also excavated the systems of meaning through which particular images come to produce and reproduce an association of women with nature, immobility, and passivity (as opposed to men who are associated with culture, movement, and action). Thomas Gainsborough’s painting *Mr and Mrs Andrews* has been subjected to some of the most rigorous critique. Here, a passive Mrs. Andrews sits immobile on a bench beneath a tree, while her husband, upright and armed with a rifle, surveys his newly acquired estate. If, as some cultural geographers have argued, landscape is a visual ideology or a particular way of seeing, it is one that both produces and reproduces a specific relation between the sexes around a relationship with nature: Mrs. Andrews, with space on her lap for a young child, to be added at a later stage, almost becomes part of the tree in Gainsborough’s painting.

**Gender, Nature, and a New Ontological Politics**

In recent years, influenced by queer theory, some feminists have become increasingly troubled by the foundations on which the sex/gender distinction itself rests. The assumption that bodies are anatomical givens over which social constructions are draped relies on particular historical, cultural, and geographical understandings of the body. Indeed, it depends on a particular understanding of what is deemed natural and what is considered social. These debates emerged at the same time as geographers were starting to question the adequacy of arguments about the social construction of nature. Society is not a realm discrete from nature that merely constructs at will: Rather, nature is produced, performed, or enacted through a heady mix of human and nonhuman relationships. The argument here is an ontological one: It concerns the makeup of reality itself, seeking to question the very assumptions on which claims about reality have been made. For Marxists, such a framework directs attention to the sensuous activity—structured as it is by specific forms of human and nonhuman forms of organization—on which reality depends: Connections are possible with the ecofeminist argument that the gendered division of labor is central to both the reproduction of inequalities and the possibilities for a liberatory alternative. For actor-network theorists, it implies a multiplication of the different actors out of which the web of life—and in turn sex, gender, and nature—is seen to be woven. In some work, the emergence of new subjects within this technologically mediated socio-natural politics is captured in the figure of the cyborg. In turn, the cyborg becomes a central trope for developing a radical feminist politics adequate to the contemporary moment.

Geographers’ engagements with gender and nature have been structured around a series of heated exchanges that have influenced and fed on broader arguments within cultural, historical,
social, and environmental geography. Throughout, the very basis on which understandings of what it means (if anything) to be a man or woman and what it means to develop a critical approach to the study of nature has been subjected to rigorous questioning. While these debates are not likely to lead to any firm conclusions—indeed the impulse is more to destabilize the grounds on which conclusions might be made—they have informed a broadly liberatory agenda. From this, new possibilities for more egalitarian relationships between people and a more sensitive relationship to ecological politics have been opened up.

Alex Loftus

See also Class, Nature and; Critical Studies of Nature; Ecofeminism; Ethnicity and Nature; Feminist Environmental Geographies; Feminist Geographies; Feminist Political Ecology; Gender and Geography; Nature-Society Theory; Race and Nature; Social Construction of Nature

Further Readings


**GENERAL CIRCULATION MODEL (GCM)**

*See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change

**GENETICALLY MODIFIED ORGANISMS (GMOs)**

The term *genetically modified organism* (GMO) is used to refer to plants, animals, and microorganisms whose DNA has been purposefully altered by the direct incorporation (or deletion) of one or more genes to introduce or modify a special characteristic. (Other terms used are *transgenic*, *genetically manipulated*, or *genetically engineered organisms*.) GMOs include pharmaceuticals such as human insulin, which was developed in 1978 and was the first product to show the business potential of the new recombinant DNA technology.

Although the biotechnology industry frequently represents the products of genetic engineering as just the latest stage in a long history of modifications introduced into plants or animals, it is only in recent decades that it has become possible to routinely transfer genes within and across species in ways that are unlikely to occur in nature. A striking difference is that while traditional biotechnology may cross one species with another, these species are always closely related (e.g., apples and pears), whereas genetic engineering has the ability to incorporate genes from one species, including bacteria, viruses, plants, or animals, into a totally unrelated species.

The extent to which GMOs diverge from natural processes has been seen as a great advantage by supporters of the technology, since it enables more effective and precise production of new plants and animals with desired characteristics compared with traditional methods that depend on random or induced mutations and crossbreeding. It has therefore been viewed as having the potential to revolutionize agriculture, food, medicine, environmental remediation, and other fields. However, an alternative view points to the potential risks of adopting a relatively untested new technology and letting its products loose in the world. There are fears that the pace of research and development of new organisms constantly exceeds the ability of policy and regulations to control potential adverse impacts. Genetic modification of animals provokes particularly strong objections for religious, ethical, and animal welfare reasons, except when it is
applied within a medical context. As a result, there has been relatively little interest in developing genetically modified (GM) animals, apart from the “oncomouse,” which was designed for medical use.

Although less contentious than GM animals or bacteria, concerns have also been expressed about GM plants. These revolve around three major issues. First, the control exercised by agricultural biotechnology corporations over farmers, such as restrictions on their right to save seeds; second, the potential environmental risks associated with GM crops, such as the development of herbicide-resistant superweeds and loss of beneficial insects and biodiversity (e.g., bees, wildflowers, and monarch butterflies); and third, the fears associated with consumption of foods derived from GM plants. Opponents point to the possibility that GM foods may result in resistance to antibiotics (due to the use of antibiotic marker genes in the production process) or contain unintended toxins or allergens. Contributing to this negative view is the fact that currently GM crops and foods have no discernible benefits for consumers, since the biotechnology corporations have concentrated on developing traits attractive to farmers and agribusiness, such as insect resistance, herbicide tolerance, and long shelf life.

GM plants developed to date are mainly food crops, notably canola, soy, cotton, and maize. They have been widely adopted in North America and a few other countries but resisted in Europe. Numerous public opinion surveys have revealed that attitudes to GMOs differ between Europe and the United States. For example, the extensive Eurobarometer study (1991–2000) found that Europeans welcomed medical applications of biotechnology to produce pharmaceuticals, vaccines, and diagnostics but were much more skeptical about its use in food production: Only a quarter of those interviewed were willing to eat food from transgenic plants. In contrast, in the United States, food products from transgenic crops have met with far less criticism, although this may partly be attributed to lack of knowledge about what people are eating.

In the United States, GM foods are unlabeled, which Marion Nestle argues deprives consumers of choice and in effect exposes them to an “experiment” in food safety. The industry, supported by regulatory authorities, argues that GM foods are “substantially equivalent” to conventional foods and therefore do not require mandatory labeling or more rigorous safety testing. In the European Union (EU), in contrast, the precautionary principle is applied: As “Novel Foods,” GM foods are presumed unsafe until their safety has been proved, and any food containing more than 1% GMO content must be labeled. European consumers are highly concerned about potential health risks because of their prior experiences with mad cow disease and other food scares. However, disquiet about GM foods is also increasingly being expressed by U.S. consumers, particularly in relation to milk from cows injected with recombinant bovine growth hormone (rBGH) to increase milk yields. Although widely used in the United States, rBGH was rejected in Canada and the EU because of concerns about adverse impacts on animal welfare and possible human health risks. Recently, opposition has arisen in the United States to the lack of labeling of GM-produced milk. The result has been a growth in demand for organic milk and the supply of GMO-free milk by major retailers. While no direct evidence exists of harm resulting from GM foods, the lack of labeling or long-term monitoring makes this difficult to assess.

Jacqui Dibden

See also Agricultural Biotechnology; Agrobiodiversity; Biotechnology and Ecological Risk; Domestication of Animals; Domestication of Plants

Further Readings


Geographies of genocide refers to (1) the study of genocide and mass violence within the broad framework of geography as a discipline and (2) the places created and transformed, real or imagined, as a consequence of genocide and other forms of mass violence.

Genocides of Genocide as a Field of Study

Genocide, literally meaning “race murder,” was coined by Raphael Lemkin during his lifelong struggle to garner international support against mass extermination. His crowning achievement, the Convention on the Prevention and Punishment of the Crime of Genocide, was adopted by the United Nations in 1948. The Genocide Convention defines genocide as any action intended “to destroy in whole, or in part, a national, ethnical, racial or religious group.” Significantly, it asserts that recognizing a genocide event is an obligation to intervene, thereby giving genocide legal status as an internationally recognized crime. With a growing awareness of the prevalence of genocide, numerous other terms have been coined in attempts to refine, expand, or focus attention. These include ethnic cleansing and the related term ethnocide (or ethnicide), democide, politicide, cultural genocide, gendercide, and femicide among others.

Genocide as a topic of study is relatively recent, and most scholars view modern genocide studies as having roots in the movement to comprehend and explain the Jewish Holocaust that emerged in the 1960s and 1970s in sociology, history, psychology, and political science. Subsequently, scholars expanded their range of interest to include broader issues of genocide in other regions and time periods. In addition to numerous case studies at a variety of scales (e.g., from coverage of an entire genocide to an individual episode of mass killing in a village on a single day), researchers have also sought to address major questions such as the motivation and rationale of the perpetrators, the role of bystanders, and the reactions of victims. One recent emphasis is comparative studies across genocidal events with the ultimate goals of prediction, warning, and prevention.

Although researchers outside geography occasionally have made laudable efforts to approach genocide from a geographical point of view, they have frequently fallen short because of failure to understand the complexities of geographic factors such as spatial variation, the flexible meaning of boundaries, place-based identity, and the multiple meanings of territory. Geographers bring to the study of genocide at least three important skill sets and perspectives: (1) in-depth regional expertise, or knowledge of places; (2) an understanding of political geography and geopolitics; and (3) mapping and spatial analysis.

A geographic perspective on genocide has much to contribute. In particular, a political geographic perspective allows for an untangling of the nexus of territory, identity, and power—issues that repeatedly play a central role in contexts of mass violence—complemented by thick, context-specific knowledge of places. It is important to understand the formation, persistence, and changing quality of territory and boundaries, and it is equally important to assess how these spatial arrangements reflect power dynamics and identity formation at multiple scales. Understanding spatial patterns and processes entails thinking outside (or inside) the concept of the state since states are not necessarily the sole or best unit of analysis to consider if we are to understand events of mass violence. A geographic approach avoids the “territorial trap,” as described by John Agnew
and Stuart Corbridge, of assuming that a focus on state activity suffices to capture or explain events within a state’s boundaries. Instead, geographers examine relations and flows across borders, understanding that each reflects changing processes. Additionally, geographers seek to understand patterns of differentiation within state boundaries rather than assuming that a state represents a container of homogeneous identity or evenly distributed access to power and resources.

The critical geopolitical element is perhaps one of the most powerful of geography’s contributions to understanding genocide. A critical geopolitical approach examines the geopolitical dimensions of genocide—how genocide is produced, described, promoted, carried out, designated, memorialized, and by whom and with what spatial objectives and results. Such an inquiry can enhance our understanding of the meanings and representations of particular places, identities, and sources of threat linked to genocide events.

A relatively recent initiative by geographers is the application of geographic mapping technologies that provide powerful tools for communicating events as they happened in the past and as they unfold in the present. This approach uses geographic information systems (GIS), aerial photography, and satellite images for digital mapping and spatial analyses. The U.S. Holocaust Memorial Museum has been a leader in applying digital mapping technologies. It hosts the Genocide Prevention Mapping Initiative, which graphically shows the widespread destruction of villages in Darfur, and it has launched its World Is Witness initiative, a “geo-blog” that aims to open “a window

As part of its Eyes on Darfur project, Amnesty International (AI) uses high-resolution satellite imagery to provide evidence of the atrocities being committed in Darfur. AI monitors villages in Southern Sudan and Darfur and posts before-and-after satellite images on the Eyes on Darfur Web site to document destruction and the establishment of structures for internally displaced persons. During August and September 2006, Arab militias attacked at least 43 villages inhabited by non-Arabs in the southern tip of Sudan. The top photo shows the village of Ligeidiba before the attacks; the bottom image shows damage as a result of the attacks.

into the lives of people affected by genocide and its long-term consequences.”

Most work by geographers on genocide and related topics has been published since 2000. Thus, the geography of genocide is a nascent field that is yet to be fully defined but one that promises to contribute much to cross-disciplinary studies.

Geographies of Genocide as Transformed Space

An illustration from a children’s primer published in Nazi Germany in 1936 shows a stereotypical (in Nazi terms) Jewish family standing on a road leading to a bright, sunny land with well-kept farms, children playing, and people fishing. A sign on the road reads “Jews are not wanted here!” the blunt message being that the world of the Germans would be better off without the Jews. This same message, which is inherently geographic, is repeated in every episode of genocide or ethnic cleansing.

Genocides and related crimes against humanity occur in particular places and are targeted at collectivities or identity groups that inhabit those spaces. The creation of an imagined “other” that is dangerous, dirty, degenerate, or in some other way undesirable is a fundamental element of every genocidal event, and the objective of the perpetrating power is to suppress, remove, or ultimately destroy this dangerous, collective other. Thus, space is transformed in the mind of the perpetrator even before any acts of destruction are carried out—indeed, the creation of an imagined space that no longer suffers the influence, presence, or physical being of the other is a key step along the way to actual genocide, which may be viewed as the spatial imaginary made real. From the victims’ viewpoint, on the other hand, these spaces to be cleansed represent geographies of exclusion and fear.

Nationalism, Regionalism, and Sense of Place

Often, the geopolitical roots of genocide can be found in nationalism and regionalism, which are, by their nature, attached to place. Sense of place is variously defined but represents an emotional (and often physical) attachment to place, such as the neighborhood where one grew up or the family farmstead one visited as a child. It evokes powerful feelings of belonging and identity. Sense of place may also attach to regional or national places or even distant places that never have been visited, such as sites of national or religious significance. Mount Ararat in Eastern Anatolia, for example, is an iconic symbol to many Armenians, most of whom have never set foot there. To many it represents lost land, lost ancestors, and lost national glory that perished in the Armenian genocide of 1915. In other words, it is a sacred place and an icon of national identity. Ararat, and many places like it, represent the irredentist impulse—the desire to reclaim lost or “unredeemed” places that, in the national memory, rightly “belong” to an aggrieved group. Likewise, when Slobodan Milosevic spoke in nationalistic terms at Kosovo Pole in 1989, the site of a major battle in 1389 between Ottoman Turks and Serbs, he invoked powerful images of Serbian identity that contributed to the episodes of ethnic cleansing that followed.

Destruction of Place and Erasure of Space

Genocide events not only devastate peoples, they also destroy spaces and places: As a culture is eliminated, its impact on the landscape recedes or disappears altogether, and the place as it once was ceases to exist, except perhaps in occasional relict features on the landscape. This process occurred all over Eastern Europe, for example, where the Jewish impact on both culture and landscape has largely vanished since the Holocaust and is found only in occasional synagogues (often converted to secular uses or abandoned entirely), overgrown cemeteries, or Jewish headstones used as building materials.

Pol Pot’s vision for a new Cambodia necessitated the deliberate creation of a new space, and the Khmer Rouge regime applied spatial logic to “delete” or “erase” known and familiar space, as well as those whose ideas reflected the “old” space. Likewise, the Khmer Rouge destroyed family structure to create a spatial vacuum; the space that had been occupied by the home, the family,
and the village society became the space of the collective as the family dynamic disappeared.

**Gender, Space, and Genocide**

In genocidal events, the roles of men and women as victims, perpetrators, and bystanders vary spatially. It is well known, for example, that the mass rape of women was widely used to produce terror, humiliation, and cultural annihilation in Bosnia, as it was in Rwanda, and as it is in Darfur. In Nazi Germany, on the other hand, soldiers were forbidden to have sexual relations, forced or otherwise, with Jewish and Slavic women, not merely for reasons of discipline but for the purpose of not defiling the “Aryan race.” Perpetrators of genocide in the main are overwhelmingly male. In Rwanda, however, Hutu women were often active participants as perpetrators, acting as informants, turning over Tutsi children who had been left for safekeeping, looking on as rapes were committed, and even participating in killing. In many or most cases of genocide, mass killing is carried out regardless of the age or gender of victims, while in some cases, as at Srebrenica in Bosnia, men and older boys are selected for extermination (being viewed as potentially more “dangerous” in an immediate sense), while women and children are set free.

**Memorialization and Tourism: Contested Postgenocide Space**

Memorialization of genocidal events frequently involves the creation of contested spaces, where different experiences and memories vie for attention and remembrance. In a sense, genocide memorials and monuments represent, as Karen Till puts it, “place based politics of memory.” In Ukraine, for example, memorials to the dead of World War II and Stalin’s mass murders, as well as monuments to nationalist heroes, frequently overshadow memorials to victims of the Holocaust, sometimes on the same sites. In other places, though, genocidal events such as the Ovaherero in Namibia are not memorialized at all, resulting in a “null memorialized space,” that is, spaces that are not memorialized despite their historical significance. Genocide tourism also creates spaces that assert particular memories and narratives. In such cases, a space may become “trapped” by history, as in the case of Osweicim (Auschwitz) where local Poles’ desires to develop land around Osweicim have been overruled in deference to the Auschwitz Museum.

*Stephen L. Egbert and Shannon O’Lear*

See also Crime, Geography of; Ethnicity; Fear, Geographies of; Hate, Geographies of; Political Geography; Race and Racism; War, Geography of

**Further Readings**


U.S. Holocaust Memorial Museum: www.ushmm.org

GENTRIFICATION

Gentrification has been the subject of extensive research and debate, with a wide range of definitions and theorizations being advanced. The term is generally traced back to Judith Glass, who suggested that middle-class people were moving into some central working-class areas of London and fixing up run-down houses. Glass highlighted that the in-movement and physical improvement of buildings was accompanied by the displacement of working-class residents, and although there has subsequently been considerable debate about the meaning of gentrification, and the relative emphasis that should be given to in-migration, upgrading, and social displacement, Glass’s definition is still encapsulated within many more recent definitions of gentrification.

Although Glass used the term in 1964, it was not until the late 1970s and early 1980s that gentrification became more widely used to refer to change occurring across a range of urban, and indeed some rural, spaces. Since this time, a series of differing forms and theorizations of gentrification have been identified, which may reflect changes in the nature of gentrification itself and/or philosophical/theoretical changes affecting geography and other social sciences. Gentrification was, for example, viewed with skepticism in the 1970s by adherents of logical positivist spatial science who routinely employed urban structural models that implied that both the physical standard of housing and the social status of residents increased with distance from the city center. Much of the early interest in gentrification indeed stemmed from the way it seemed to contradict such models given that middle-class people seemed to be moving into areas close to the center of cities.

Gentrification studies were indeed an important impetus in the critique of positivist urban models and the development of alternative approaches. Behavioral perspectives, for instance, emerged focused on identifying the motivation for inner-city living, while managerial and structuralist approaches were used to consider the role of governmental policy and the availability of finance. By the early 1980s, such differences were often expressed in terms of production-side and consumption-side perspectives, with a trenchant debate emerging between their exponents, although there has been a subsequent reappraisal of this dualistic construction of gentrification studies, as well as the emergence of new theoretical emphases related, at least in part, to the incorporation of further theoretical perspectives into geography. By the early 1990s, it was possible to identify at least five distinct, albeit overlapping, approaches to gentrification studies, each of which are briefly outlined in this entry.

Gentrification as Class Colonization and Displacement

From Glass’s initial comments, notions of class have been central to conceptions of gentrification. Class is, however, a very contested and congested concept, with both widely differing conceptions of class advanced and considerable debate as to the overall significance of class. In the context of gentrification, different concepts of class have been advanced by advocates of production and consumption explanations. Among the former, emphasis is often placed on ownership and control of property and financial resources, with gentrifiers being viewed as people who are able to gain control over areas of space through outbidding others in land markets and investing resources in purchased properties. In consumption-side accounts, class tends to be viewed as an occupation-related concept, it being suggested that a “new middle,” “service,” or “cultural new” class of creative, professional, and managerial occupations has emerged in association with the growth of postindustrial activities in the second half of the 20th century. It is claimed that this group has been particularly significant in major global cities and a desire for a place of residence close to these locations stimulated the desire for inner-city residence, as well as gentrification of the surrounding towns and rural areas.

Some recent work in class analysis has sought to integrate capital- and occupational-centered concepts of class, suggesting that contemporary class positions are more multidimensional and complex than implied by the dichotomous and gradational concepts of class used in many production and consumption conceptions of class, respectively. Such ideas have been drawn into studies of gentrification, it being suggested that
while some parts of cities such as London and New York may be experiencing so-called supergentrification by financial services workers with very high levels of economic capital, other areas of these cities, and many other provincial cities, are sites of gentrification by less affluent managerial and professional workers. Earlier, Damaris Rose coined the term *marginal gentrifier* to refer to people who may be undertaking gentrification activities but are far from affluent. People so identified have included artists, first-time house buyers, renters who are forced to become property owners by the sale of properties by landlords, and people who live in gentrified areas due to workplace, transport, or other constraints. It has been argued that marginal gentrifiers may be very important in the early stages of gentrification, although they may themselves be subject to displacement from an area by more affluent social groups. Ideas of diverse middle classes, marginal gentrifiers, and stage processes have also been advanced in relation to the gentrification of rural areas.

While considerable attention has been paid to the class position of gentrifiers, gentrification has a further class dimension in that it classically involved the displacement of working-class residents. Examination of the class position of the displaced has received rather less attention than that of the gentrifiers, an omission that not only may reflect the methodological difficulties surrounding locating the displaced as well as recognition of a range of nonclass differences and identities but may also reflect unacknowledged transformations in working-class living and employment conditions.

### Gentrification as Capital Investment

Gentrification appears readily linked to population movement, it being widely portrayed as the “back-to-the-city” movement of people. This understanding of gentrification has been challenged, notably by Neil Smith, who argued that not only were many inner-city gentrifiers migrants from other urban areas but also, and more significantly, that gentrification should be seen as a process of capital rather than population movement. Smith developed what was widely viewed as a production-side theory, in which gentrification was seen as a manifestation of the uneven circulation of capital and, specifically, the product of processes of devalorization and revalorization in which so-called rent-gaps emerged whereby current use of an area yields financial returns that are significantly lower than those available under some alternative land usage. The existence of such gaps means that there are opportunities for high-level profits by those people or institutions that invest capital—in the broad sense of products and labor power as well as money—in this new use. It was the appearance of rent-gaps in the inner city that created the conditions for a back-to-the-city movement of capital, as resources that were previously flowing out of these areas became attracted back into them because of the opportunity of investing in gentrifying housing (Figure 1). Gentrification was for Smith a process of property investment and gentrifiers in effect property developers who reap the rewards of converting properties from some lower-value activity.

Smith’s capital-centered account of gentrification became the subject of considerable criticism, with at least three lines of debate emerging. First, concerns were expressed about the concept of rent and its relationship with other, largely more neo-classical economic concepts and with empirical data sources. Second, reservations were expressed about the motivational implications of the rent-gap thesis. Studies of residential decision making often suggested that gentrification activity might be stimulated by a range of motivations other than financial profit, including proximity to the workplace and avoidance of escalating commuting costs; access to retail, leisure, and cultural activities; and a desire to live in a location bearing markers of social distinctiveness and status. Third, the rent-gap thesis fostered consideration of the range of agents involved in gentrification. Smith identified types of gentrifiers based on the way refurbishment activity is undertaken and profits realized (Table 1), but his concept of gentrifiers as developers was criticized as being too all-encompassing and stretching the term *gentrification* beyond any meaningful limit. The presence of new-built construction and intersectoral developments encompassing more than housing was also seen to pose definitional problems, although for others, including Smith, these features are indicative of changes in the character and scale of gentrification.
Consideration of agents of gentrification emerged within consumption- as well as production-focused studies. Studies of locational decision making by householders, for instance, suggested that there were significant lines of social difference beyond their class that characterize gentrifiers. For example, retail, leisure, and recreational “consumption” activities identified as significant migrational motivations implied that gentrifiers were relatively young and perhaps living in single-person or childless households. It was argued that the emergence of gentrification might relate to demographic as opposed to class change, with the postponement/rejection/breakdown of marriage and postponement/rejection of child rearing both leading to the creation of more single-person households and childless couples. More generally, consumption-side studies often argued for disaggregation of gentrifiers beyond a simple designation of being middle class, or indeed from a particular middle class, toward recognizing that a variety of forms of social difference might be of significance. As well as studies highlighting the significance of age and household structure, research emerged linking gentrification to sexuality, gender, ethnicity, and race.

While the recognition of social differences other than class can be seen as simply adding further detail to what is still an essentially class-driven
process of colonization and displacement, it also led to questioning of whether gentrification should, by definition, be seen to involve class. From the 1980s, a series of studies explored whether gentrification could be explained through factors other than class, and there was also a questioning of the overall value of the term *gentrification*, with some earlier exponents even calling for its abandonment. Other responses, however, included the construction of newer more integrated theories and calls for paying greater attention to the epistemological aspects of gentrification theory.

**Table 1** Types of gentrifiers, as identified by Neil Smith


Gentrification, Reproductive Labor, and Gender

Recognition of difference is of significance to, and was very much fostered by, considerations of gender, where three distinct lines of arguments emerged. First, it was suggested that gentrification was, at least in part, an outcome of rising female participation in paid employment, which led to rising numbers of both high-income single-women households and dual-income households that could afford to engage in gentrification activities. Second, urban gentrification was viewed as a response to the pressure placed on the performance of reproductive labor by rising female paid employment, it being argued that the rising numbers of householders sought to live in inner-city locations in order to minimize journey-to-work costs and to facilitate the substitution of market-produced commodities for household labor.

These two interpretations have an explicit urban bias in that Western cities tend to have higher rates of female paid employment and contain high levels of accessibility, service, and retail provision. Reproductive labor may also play a role within rural gentrification, with rural in-migration often being stimulated by the onset of child rearing and by perceptions of high levels of personal and community service provision in rural areas. However, service provision, the performance of reproductive labor, and household structures do not necessarily map onto rural-urban differences, with a series of urban studies from the late 1990s highlighting both the presence of children in gentrifier households and the significance of child care and education issues in locational decision making.

A third line of argument relates gentrification to a broad transformation in gender relations, it being suggested that female gentrifiers may be drawn to areas where there is perceived to be a lessening or a dilution of patriarchal relations. Conversely, it has been argued that in a rural context, patriarchal gender relations act to sustain, and are themselves sustained by, middle-class, child-related in-migration. On the other hand, studies have also highlighted how rural locations can be sites for gentrification because they are perceived as localities where nonconventional household and partnering relations are practiced.
Gentrification and Culture

Culture has long been a component of gentrification studies, although it was only in the 1990s that its significance became the subject of extensive reflection and debate. Many early references to culture were linked to the formation of behavioral desires to live in particular locations, such as the inner city or the countryside. Reference to culture was, however, also made in arguments relating to class, where culture was seen to be of significance to both the capital- and the occupational-centered conceptions of class. References to the “cultural new class” in the latter case, for instance, clearly supported that culture was of significance, it being argued not only that there were many occupations in the postindustrial economy centered on cultural work but also that people in this class held particular cultural values. David Ley, for instance, argued that members of this class tended to hold countercultural views associated with the hippy movement of the 1970s, albeit suitably modified to fit within the contours of a middle-class lifestyle. Connections have been drawn from asset-based forms of class analyses that make reference to notions of cultural as well as economic capital, which in turn can be linked to capital-centered concepts of class and gentrification that made reference to the commodification of culture. For example, Sharon Zukin argued that the presence and residential living style of artists who had converted industrial loft spaces in SoHo, New York, were of appeal to the more affluent middle-class group and as a consequence became the subject of marketization by property developers.

Attention has also been drawn to the representations of gentrification by both academics and others. Smith, while renowned for his material emphasis on notions of class and capital, has long made reference to issues of cultural representation, noting how a language of “frontiermanship” was often employed in descriptions of gentrification. He also highlighted the presence and use of images of nature, adventure, and history in descriptions of gentrification and the relationships and differences between the use of this term and others such as regeneration. The significance of place is also highlighted as gentrification is promoted through notions of “city living” and a “rural idyll.” While seemingly quite contradictory spatial evaluations, it has been argued that they may have a common element—that is, an aversion to suburban space. Attention has also been drawn to the relationships, and differences, between cultural representations of gentrified space and the performance of everyday life in such spaces, through concepts such as the gentrification aesthetic and habitus.

Conclusion

Gentrification has been a term that has been the subject of debate and criticism since its emergence in the mid 1960s, and while there have been repeated calls for its abandonment, it continues to excite interest and contention. Gentrification has been theorized in a wide range of ways. Here, five rather different approaches have been outlined. Not only are there clear lines of overlap between them, but also many nuances within each line of argument have been omitted for the sake of brevity. Furthermore, there are also some further lines of argument that could have been included, including recent discussions related to the role of neoliberalism and the state in contemporary gentrification, the variant forms and locations of gentrification, globalization, the significance of displacement, and the geographies and scales of gentrification. At the present moment, gentrification seems likely to continue to be an important component and catalyst of geographical study and change.

Martin Phillips

See also Circuits of Capital; Class, Geography and; Ethnic Segregation; Gated Community; Gays and Lesbians, Geography and/of; Housing and Housing Markets; Ley, David; Marxism, Geography and; Racial Segregation; Rent-Gap; Segregation and Geography; Smith, Neil; Urban Geography; Urban Spatial Structure

Further Readings

Geocoding is the process of finding geographic coordinates (such as latitude and longitude) for a given feature, expressed as, for example, place name, street address, or postal zip code. Geocoding is useful in many applications, such as responding to emergency calls, mapping and analyzing information from text sources (such as terrorist incidents reported in newspapers), or finding directions to an address. A geocoding process normally has three components:

1. The input features to be geocoded, which are specified as addresses or place names
2. A reference database, which contains a comprehensive collection of addresses or place names and their corresponding coordinates
3. The matching procedure, which finds each input feature in the reference database and retrieves its coordinates

Among the above three components, the organization and structure of the second component (i.e., reference database) may vary from country to country. Each input feature must contain information about its location, such as the street address, the postal code (or at least part of it), or the name of an area. In the United States, there are three main methods of geocoding, according to the reference database that is used: (1) geocoding by street address, using Census TIGER (topologically integrated geographic encoding and referencing system) data files or parcel databases; (2) geocoding by postal code, using databases of zip code areas; and (3) geocoding by place name, using standard geographic name databases.

### Geocoding by Street Address

To geocode an address, a reference database of street networks (such as the U.S. Census TIGER data files) can be used, where every existing street segment is stored with its name and addresses at its start and end nodes (for each side of the street). If a given feature address is not at the start or end of a street segment, the geocoding process then interpolates the position of the address, assuming that houses (addresses) are evenly distributed along the length of the street, with odd-numbered addresses on one side and even numbers on the other side. As an alternative to street databases, parcel databases may also be used to geocode addresses. A parcel database contains each parcel (area) and its address. Each input feature address...
will be geocoded to the center (centroid) of the parcel that has the same address.

**Geocoding by Postal Code**

If the input features are specified as zip codes, for example, 5 digits or 5 + 4 digits in the United States, each feature can be geocoded at the centroid (center) of its zip code area. However, since zip code areas are usually much larger than the parcels, the geocoding result with zip codes is not as precise as with parcel data or street networks.

**Geocoding With Place Names**

The input features may be specified as place names, such as cities, towns, villages, and so on. To geocode such data, a comprehensive geographic name database is needed to find out the coordinates of each feature. In the United States, there are two official geographic name databases, which can be used as the reference data set for geocoding: (1) the GEOnet Names Server (GNS), which is the official repository of standard spellings of all foreign place names (outside the United States) and their coordinates, and (2) the Geographic Names Information System (GNIS), which is the official repository of domestic geographic names (inside the United States) and their coordinates.

**Reverse Geocoding**

Reverse geocoding is the process of finding the address for a given pair of coordinates. For example, one may want to find nearby place names or services (such as restaurants or gas stations) for a given latitude or longitude, which may be provided by a GPS (global positioning system) device. The reversed geocoding process is similar to the geocoding process in that both need a reference database. They are different, however, in that the input and output are reversed and the matching procedure is different.

*Diannsheng Guo*

See also Coordinate Systems; Earth’s Coordinate Grid; Geodesy; Ground Reference Data; Place Names; Toponymy

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**Further Readings**


GEOnet Names Server: http://earth-info.nga.mil/gns/html


**Geocollaboration**

Geocollaboration is collaboration among place-based subjects that is facilitated with and through geographic information and technologies. Geocollaboration is a field of study that is multidisciplinary in nature, incorporating theory and methods from human-computer interaction (HCI), computer science, and psychology. Within geography, research on geocollaboration is generally situated within the realm of geographic information science (GIScience). However, it is a topic of cross-cutting relevance to geography as a whole, due to the emphasis that can be placed on either the technological aspects of geocollaboration or the relationship between geocollaboration and social mediation and/or organizational collaboration.

From the technological perspective, the development of systems to support geocollaboration primarily falls under the broader category of computer-supported collaborative work (CSCW), or the study of how people collaborate and the development of computer-based systems that enable people to collaborate in order to achieve common goals and/or make decisions, sometimes referred to as “groupware.” CSCW systems are most often developed based on the use of a given system in terms of the place where collaborators are located (colocated or remote) and the time dimensions of the collaborative work being
undertaken (in real time or asynchronously). Figure 1 shows the place-time dimensions of geocollaboration in a matrix form and provides brief examples of each dimension.

Additionally, geocollaborative system development takes into account issues of awareness such as co-collaborator presence and activity, the resources available to the group, the status of collective objectives and goals, common ground, and many other CSCW issues that are beyond the scope of this discussion. Unique geographic issues in geocollaborative system development include effective use of geovisual representations such as map-based graphical annotations for representing location-based ideas, the arguments and perspectives of collaborators, the use of geospatial data standards for system interoperability, and group cognition of spatial information.

The research perspective of geocollaboration as a social mediation and/or organizational collaboration de-emphasizes the specific role of information technology as a mediator for collaboration and looks at the broader social contexts that collaborative processes are occurring within. Social contexts are examined to identify barriers to collaboration such as trust, privacy, and the effects of organizational culture and jurisdictional scale. Using an example from crisis management, collaboration activities across federal, state, and local officials can be examined to understand whether or not officials collaborated effectively across jurisdictional and geographical scales in response to a national disaster.

Another research perspective on organizational geocollaboration activity looks at how geographic information portals on the Internet can potentially encourage organizations to share geographic information resources with the objective of facilitating better collaboration. A primary example of this can be seen in the development of spatial data infrastructures (SDIs). SDIs provide administrative infrastructures such as data-sharing
policies, documentation, and procedures and technological infrastructures such as data interoperability, discovery, and retrieval, which together ultimately allow for the dissemination of geographic information between organizations.

One of the newest research perspectives of geocollaboration as social mediation is examining the integration of geographic information into so-called Web 2.0 technologies. Succinctly, Web 2.0 is the notion of decentralized, user-generated content on the Internet that can be easily shared among people. Examples of Web 2.0 technologies are blogs, wikis, and geotagging of information such as photographs. Geocollaboration from the Web 2.0 perspective thus entails forms of collaboration that do not necessarily have a direct objective such as decision making but rather are decentralized collaborative processes that work toward broader goals that may be of benefit to society. For example, the OpenStreetMap project was developed to create “a free editable map of the whole world” where people can “view, edit and use geographical data in a collaborative way from anywhere on Earth.” In addition to calling this type of activity geocollaboration, the term *volunteered geographic information*, or VGI, has also emerged to describe the development of geographic information by individuals.

One other aspect of geocollaboration activity as social mediation is the use of mapping “mashups” to facilitate collaboration. A mashup is a Web-based application that is composed of several heterogeneous components to create a new application. A common example is the use of Google Maps as a base map that is combined with other information that is of prime relevance to the application. From the geocollaboration perspective, mapping mashups are powerful collaborative mediums that can be quickly generated by nongeographic technology experts to fulfill gaps in social needs. For example, during the Hurricane Katrina disaster of 2005, the scipionus .com Web site was a grassroots effort developed to provide location-based information about areas affected by Hurricane Katrina. Using an online mapping mashup, visitors to the Web site were able to enter status information about areas affected by the hurricane. Use of the site grew immensely as the general public sought location-based information on the disaster area that was not available through regular mediums such as the media.

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**See also** Collaborative GIS; MacEachren, Alan; Neogeography; Participatory Mapping; Public Participation GIS

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**Further Readings**


OpenStreetMap Project: www.openstreetmap.org


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**GeoComputation**

The GeoComputation conference series defines geocomputation as “the art and science of solving complex spatial problems with computers.” This definition highlights the key features of geocomputation that distinguish it from other subdisciplines within geography. First and foremost, it is about solving problems with computers. These problems are also sufficiently complex or involve sufficiently large data sets that a computer is required to solve them. Finally, the conference series definition describes geocomputation as
both an art and a science. Geocomputation is as much about creatively developing new data structures and algorithms for geographical analysis as it is about rigorously testing those algorithms and comparing them with existing algorithms and methods.

**Connections to Other Fields in Geography and in Other Disciplines**

The problems that geocomputational methods solve span the breadth of geography, including applications in geomorphology, ecology, urban geography, transportation geography, climatology, and medical geography.

In addition to the ties to application domains in which geocomputational techniques and methods are used, the field of geocomputation has connections with several other methodological subdisciplines within geography, including remote sensing, geographic information science, spatial analysis, and geovisualization.

Many data sources for geocomputational data structures and algorithms come from remote sensing, so many of the issues that arise in remote sensing are also dealt with in geocomputation. A prominent issue from remote sensing is the size of data sets that can be involved in this research. Remote sensing satellite systems can generate up to gigabytes of data each day. To best use data sets of this size, especially those that are continually growing in size, data structures allowing for efficient compression of the data and algorithms that can equally rapidly analyze raster data sets of that size need to be developed.

Geocomputation connects with the broader field of geographic information science (GIScience) by contributing to the computational aspects of GIScience. Sample topics in this overlap include data and process modeling with algorithms such as cellular automata and agent-based simulations, how best to represent and analyze uncertainty in spatial data, what data structures and algorithms are effective for representing and analyzing spatio-temporal data, and contributing to the computational aspects of concept mapping and ontologies.

As data sets grow in size and complexity, many of the techniques developed in spatial analysis are entering the geocomputational realm. As data sets get bigger, the statistics used to analyze them must be performed on a computer. The connection between spatial analysis and geocomputation is more substantial than simple application of previously developed methods; the greater processing power of computers permits new forms of analysis on these data sets. Statistical methods, such as Moran’s I autocorrelation statistic and regression, can be adapted for spatial data to become the local Moran’s I statistic and geographically weighted regression. Making even more use of the computer’s processing power, artificial intelligence and data mining techniques developed in statistics and computer science are being adapted and applied to geographic data.

Geocomputation has connections with geovisualization and the newly emerging field of geovisual analytics. Geocomputational methods contribute to these fields through the data compression, summarization, and filtering methods needed to reduce very large data sets to a size that is viewable on a computer monitor. Additionally, as ways of visualizing the results from the analytical methods developed in geocomputation are developed, geocomputation contributes to geovisual analytics.

In addition to its ties with other parts of geography, geocomputation has ties with other disciplines, most prominently computer science and statistics. Many of the data structures used in geocomputation originate within computer science, especially computational geometry, although adaptations to fit the constraints of spatial data are common. Likewise, the algorithms developed for analyzing data, especially artificial intelligence techniques, connect geocomputation to computer science. Also, the data mining techniques and analysis methods mentioned above, such as geographically weighted regression, connect geocomputation to statistics.

**Topics in Geocomputation**

This section gives an overview of the data structures and algorithms that are developed and used within geocomputation. A comprehensive survey of all the topics addressed within geocomputation is beyond the scope of a single encyclopedia entry, so the following section gives a sample of the research issues within geocomputation. For a fuller account of the topics researched within
One branch of geocomputation focuses on the development of computational data structures for spatial data. These developments revolve around two themes: (1) the increase in the size of geographic data sets and (2) the difficulties of representing and accessing two-dimensional data when computer disks use a one-dimensional layout, more like a list than a grid.

To cope with the increasing size of geographic data sets, multiple-scale or multiple-resolution data structures have been developed that allow algorithms to access a broad overview of the data quickly and only focus on the detailed data that are necessary for the task being completed. This idea has borrowed the multiple-scale representation from the mathematical concept of Fourier analysis. An example of this is the representation of a demographic variable, such as the percentage of the population that is African American, for all census tracts within the United States. The highest-level overview reports the data aggregated to the state level, giving the percentage for each state. The middle level, at the county level of aggregation, stores not only the aggregated value for each county but also the departure of the county’s value from the relevant state’s value, so that the sum of the state value and the county departure gives the value for the county. This permits the analysis to look at geographical factors and trends that operate only at the county scale and that may be overwhelmed by the state factors and trends if the true values rather than the departures were used. Similarly, the tract-level departure from the county’s true value is stored at the most detailed level of the data set, so that the value for a census tract is the sum of the state value, the county departure, and the tract departure. Another benefit of this type of data structure is that only the detailed data for the area of interest need to be loaded into the computer memory. To examine a variable at the census tract level for a given state, such as Pennsylvania, only the data specific to Pennsylvania are loaded rather than loading the entire file of census tract data for the United States.

The second problem of how to represent geographic data arises from the linear way in which data are arranged on a computer disk, and the implications that this has for quick access to parts of the file. Computer data are stored as a very long list of bits, and it is easy for a computer to load into memory data that are a contiguous line on the disk. However, it takes longer to load many disconnected lines, even if the lines add up to the same length as the contiguous line. In a geographic setting, it is common to load the data for a geographically contiguous region, such that if data for Place A are being loaded into memory, the data for Place A’s neighbors will usually also be loaded into memory. Therefore, it is desired to have the situation whereby two places that are near each other geographically are also likely to be close to each other on the disk to maximize the likelihood of only having to read a single line on the disk. A data structure called a quadtree, along with a way of storing it on disk called the Morton ordering, achieves this goal. While quadtrees are specific to raster data sets, variants for vector data sets have also been developed.

In addition to the data structures developed to address the computational challenges of geographic data, research in geocomputation has developed and examined algorithms to collect and analyze these data.

A growing section of geocomputation involves the collecting and organizing of information gathered from Web sites, RSS (Really Simple Syndication) feeds, and other similar forms of digital media. This research typically involves scanning large amounts of text documents to extract place names and organize texts, such as online news articles, based on where they take place. Challenges encountered in this research center on disambiguation, such as trying to distinguish between place names that are words with nonspatial meanings (such as China—the country and the porcelain) and multiple places with the same name (such as Georgia—the state in the United States and the country in the Caucasus).

Other algorithms, particularly those in the sector of geocomputation connected with geovisualization, focus on enabling decision support for geographic problems. Many of these examine different ways of displaying the data on the computer monitor, to determine what way or ways are most effective at presenting the data so that the user can both understand and explore the data set. A particular approach to decision support specific
to geocomputation is the use of expert systems for geographic decision support. Expert systems are a tool developed within the artificial intelligence community for complex problems such as quickly diagnosing an illness based on a few symptoms. In geocomputation, they can be applied to the challenges of developing effective visualizations and decision support applications for determining whether or not a place is at risk for a hazard, such as landslides. Another research focus for assisting decision support systems examines ways of representing and analyzing the various types of uncertainty in geographic data sets. As the analysis and visualization tools mature to the point of being used to assist decision makers and officials, these tools need to be able to convey not just the information about the problem but also the uncertainty in the information. This uncertainty can take many forms, not just the confidence intervals that are standard in statistics. Some other types of uncertainty include the age of the source—older information about a rapidly changing situation is unreliable—and the trustworthiness of the source; one application domain of these tools is homeland security, where deliberate misinformation is a concern. For these geocomputational tools to be as useful as possible for decision support, they should be able to represent and analyze these types of uncertainty and others in the data set in addition to representing and analyzing the data set itself.

Many algorithms have been developed within geocomputation for the analysis of geographic data, not just the representation of data. Some of these analytical methods, such as geographically weighted regression (GWR), discern trends in the data, much like regression does in standard statistics. While regression finds correlations between two variables across an entire data set, GWR searches for correlations between two variables across only a geographic subset of the entire data set and can then provide an analysis of how the correlation coefficient and its statistical significance varies across the geographic extent of the data set. Similarly, statistics to detect autocorrelation have been adapted to a geographic setting. Autocorrelation statistics were originally developed to analyze time series to determine how likely it is that an observation is similar to observations immediately before and after it in a time sequence. Spatial autocorrelation tests adapt these ideas to determine how likely it is that an observation is similar to observations in nearby areas.

Similarly, techniques from data mining that facilitate the statistical analysis and exploration of large data sets are being applied to large geographic data sets, such as the U.S. decennial census. These can range from rigorous statistical approaches such as discriminant analysis to computational heuristics such as decision trees and neural networks. A frequent criticism of data mining techniques in geocomputation is that they function much like a “black box.” A large amount of data are given to a computer program, which then applies complex and often hard-to-understand algorithms to the input data and gives an answer about the task being analyzed. Because of the complexity of the algorithm, however, it is hard for most users to understand how the computer program arrives at the answer it gives. This lack of transparency can make some of the algorithms hard to use. Additionally, many geocomputation algorithms require the user to supply parameters that affect the answers they give, yet it can be difficult for a user to determine what the appropriate value of those parameters should be, compounding the difficulty of using these techniques.

Two commonly used sets of algorithms for analysis in geocomputation are for classification and clustering. These two related concepts both create groups of data based on their attributes, and both are often referred to as clustering algorithms. For clarity in this entry, the terms classification and clustering are used as follows. Classification algorithms, such as K-means divide the data set into a prespecified number of groups and ensure that each individual datum belongs to exactly one group; the groups formed from this algorithm do not need to be geographically contiguous. One application of this type of algorithm is the classification of remotely sensed images into land cover classes. Clustering algorithms search to find groups of data that usually form a single contiguous geographic shape and that have a particular quality that is being searched for, such as a higher than expected rate of a disease. In this example, each cluster is an area of high rates of the disease being studied, and clusters can overlap each other. Thus, each individual datum can belong to zero, one, or more than one cluster simultaneously.
Algorithms for optimization analysis have been developed in geocomputation. These optimization algorithms can include the clustering algorithms described above because they seek parts of the data set that have the highest (or lowest) value of some function. In the clustering example above, the function is the rate of the disease. Typically, the data sets are too large to simply check every possible location within a reasonable amount of time, so a heuristic, or rule of thumb, is needed. These heuristics are frequently borrowed and adapted from artificial intelligence research in computer science. Common examples are genetic algorithms and simulated annealing. In addition to the “black box” and parameter critiques described above, another drawback of these heuristics is that they cannot guarantee that they return the best solution to the optimization problem; because not every part of the data set is examined, it is always possible that a better solution remains in the unexamined portion of the data set.

Last, geocomputation involves methods of modeling geographic processes. Two common approaches to this modeling are cellular automata and agent-based models. Cellular automata operate on a grid of the area being studied, where each grid cell has some geographic attributes assigned to it. An example of this is a physical landscape with the elevation, presence of water, and level of urban development represented. The cellular automata model then has rules governing some process, such as urban growth. As the model runs, the grid cells of the nonurban region get converted to urban cells based on the rules governing urbanization; for example, any cell with five or more urban neighbors will become an urban cell. These models can then be run and compared against the real-world situation to determine if the rules are valid. In this way, cellular automata models can provide valuable insights into the rules governing geographic processes. While cellular automata models work well with raster data, agent-based models are analogous to vector data. In agent-based modeling, which is often applied to objects that move, such as people or wildlife, each person or animal being modeled is considered an agent. Similar to the rules that govern cell behavior in a cellular automata model, there are simple rules that govern agent behavior in agent-based modeling; for example, an agent representing a wild animal will move toward a river if the animal is thirsty. Both these modeling approaches make use of the idea of complexity, whereby the interaction of a small set of simple rules can create many complicated and interesting patterns.

Conclusion

Geocomputation lies at the intersection of geography and computer science, contributing to and borrowing from a range of subdisciplines both within geography, such as geographic information science, spatial analysis, remote sensing, and geovisual analytics, and outside geography, such as data mining in statistics and artificial intelligence, data structures, and database management in computer science.

Jamison Conley

See also Agent-Based Models; Cellular Automata; Geographically Weighted Regression; GIScience; High-Performance Computing; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Data Mining; Spatial Data Structures; Spatial Optimization Methods

Further Readings


Geodemographics uses the close links between where a person lives and the lifestyle choices that the person makes for various economic, social, and political applications. It is the analysis of the demographic and socioeconomic characteristics of people based on their location, although it is often viewed as a data exploration tool rather than a method of hypothesis investigation. Developments
in geodemographics go hand in hand with advances in geographic information systems (GIS) as geodemographics heavily uses the mapping of classification schemes. Analysis consists of data acquisition and cluster-based classification to produce profile groupings of similar attributes, which are then assigned to contiguous geographic areas. Marketing companies, academia, and government use these classification schemes for a variety of applications, such as predicting the usage of public services and understanding consumer needs. Current topics of interest within the field of geodemographics are statistical relevance, public accessibility, temporal sensitivity, and combining geodemographics with other geographical fields such as remote sensing.

Data Collection
Data necessary for geodemographic analysis will vary depending on the goals of the project but will always consist of two components—the target group and the geographic unit of study. The target group consists of individuals of specific characteristics and is measured through proxy variables. For example, high-income households might be measured with the proxy of how many cars a household possesses. Proxy variables include but are not limited to information concerning socioeconomic status, demographics, durable goods, usage of public assets, and any other information concerning the lifestyles of individuals and families. The scale of the geographic unit of study will also depend on the goals of the project but will almost always follow preexisting administrative boundaries, such as postal codes, census tracts, or census blocks. GIS is used to tie individual data to locations, assist in analysis, and geographically represent the data. General demographic and socioeconomic data are collected from existing public data sources, such as the census and administrative surveys. Marketing firms often need to buy or privately fund syndicated market research group surveys, which contain extensive detail but do not have many respondents.

Classification
The main goal of a geodemographic analysis is to produce a classification scheme of neighborhood profiles. Classification takes all the areas under analysis and groups them into a smaller number of classes ranging from 10 to the 150 types offered by some marketing firms. Over time, classes have been offered at increasingly fine scales, ranging down to the household and, at times, even the individual. The number of classes will depend on the needs of the project and how much detail is wanted. Classification is accomplished by placing all proxy variables of interest into a factor or cluster analysis with a predetermined number of classes. The demographic and socioeconomic characteristics of each class are summarized, and often a short label is assigned to each class that gives an impression of what that class represents. Companies selling geodemographic classifications will also usually provide a picture or drawing representing each class. The classes can then be mapped in a GIS, but care should be taken to produce a meaningful and realistic map structure that is easy for the user to understand.

Applications
Applications of geodemographics can be broadly split into public and private interests. Major private companies use geodemographics for profiling of consumers into categories that can then be easily marketed and catered to. This practice is called niche marketing. Companies will often conduct small detailed surveys and buy the geodemographic classifications of those areas from larger companies. They then compare the surveyed customers with the geodemographic baseline for the entire area, allowing them to conjecture information about their customer base. This information is used for a variety of applications, such as further survey designs, product placement, retail planning, development of new shopping centers, site selection, household and rent pricing, and scheduling of television and other media advertising. The main public sector uses of geodemographics are within government initiatives and nonprofit organizations. Local governments can use geodemographics for better planning of resource deployment, such as local policing, food banks, health services, schools, public libraries, and other government-provided services. Often, geodemographics is used to locate and understand where areas of high deprivation are located. Another application
is the use of geodemographics by political campaigns to locate potentially friendly voter blocks. Nonprofit organizations employ geodemographics both to better locate areas of need and for fund-raising purposes.

**Criticisms and Future Research**

The field of geodemographics has been heavily criticized. Mapping classifications presents limitations by implying that populations are uniformly distributed, both numerically and socioeconomically or demographically. Maps also give the impression that changes occur only at the borders between classed areas, instead of demonstrating the more likely gradual change occurring in neighborhoods. Using GIS methods of overlay with remotely sensed imagery as well as creating boundaries of classifications that are more sensitive to changes over space are some of the methods being explored to correct these issues. Generalization within geodemographics is criticized as a practice that may actually be harmful to neighborhoods. By giving individuals within an area a general label and then marketing to that label, the small changes introduced into a neighborhood based on these marketing decisions may actually further validate the definition and place neighborhood identity beyond the control of residents.

Future work in geodemographics has many potential paths, but most research is being done in academia. Web-based geodemographics has been introduced as a means of easy accessibility and transparency and, more important, as a way of promoting community involvement in classifications by allowing user feedback. As research interests in neighborhood effects increase, geodemographics is proving useful in studying what a neighborhood is, how to define it, and what kind of influences it has on the people living there. There is also some work being done on making geodemographics more statistically relevant and providing some degree of validation. One of the areas that marketing firms are exploring is making geodemographics more in step with the realities of mobility. A geodemographic classification of a city may be completely different in the afternoon, when people are at work, than in the morning or evening, when they are at home.

*Marta Jankowska*

**Further Readings**


**GEODESY**

The literal meaning of *geodesy* is “division of the Earth,” and it can therefore be said that at its most fundamental level, the subject is concerned with positioning on the surface of the Earth. More narrowly, the subject is understood to apply principally to applications with an extent or accuracy that demands a consideration of the true shape of the planet (in contrast with surveying, which may be more concerned with flat Earth approximations).

More broadly, however, geodesy necessarily encompasses the range of mathematical and scientific topics that relate to the determination of the shape and size of the Earth, its representation in coordinate terms and computations within these coordinate systems, map projections, positioning, and height determination techniques (in particular satellite-based systems). It can therefore be seen that geodesy is of direct relevance to geography in that it establishes the essential underlying coordinate reference systems for use in mapping and related spatial information activities.

This process can be thought of in a hierarchical fashion or as a logical sequence of required steps. First, one needs to know the shape and size of the...
Earth, which one finds from several different types of observation. The surface that it is required to determine is known as the geoid, which is defined as that equipotential surface (one perpendicular to gravity) that most closely corresponds to mean sea level. Its long-wavelength components are generally found from an analysis of the perturbations of satellite orbits from the simple Keplerian model, since these are caused by major gravitational trends. Its short-wavelength components are determined principally from a combination of direct observations of gravity anomalies (on the surface, through airborne gravimetry, and from dedicated satellite missions) and analysis of satellite altimetry data over the oceans. The link between gravity and shape is one of the classical mathematical problems of geodesy, and much research is devoted to the optimization of the algorithms used.

The traditional method for the determination of Earth’s size was by terrestrial observations of angles and distances. These were generally made in linked chains of triangulation that were sometimes carried out along a meridian with the specific intention of gaining information on Earth’s size; more generally, these were carried out to provide a framework for mapping. While the results of these traditional geodetic observations may still in many parts of the world (and not necessarily the least developed) form an essential component of the coordinate framework, the primary techniques for the determination of the size of the Earth (i.e., determining the relative coordinate values for key global reference points) are space based. These include the following: (a) very long baseline interferometry (VLBI), in which pairs or sets of radio telescopes make mutual observations to extragalactic sources of radiation, and baselines are inferred from time delays; (b) satellite laser ranging (SLR), in which ground stations fire lasers that are returned by retroreflectors aboard satellites; (c) the global positioning system (GPS) or any other similar global navigation satellite system in which receivers make observations of electromagnetic signals broadcast by a system of orbiting satellites; and (d) Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), in which the Doppler shift of a signal received at a dedicated satellite from a ground station is the fundamental measurable.

All these different observations contribute to the establishment and maintenance of the International Terrestrial Reference Frame (ITRF), which is the primary global coordinate system. It is maintained and disseminated by the International Earth Rotation Service (IERS). It is desirable to determine the transformation from any traditionally established coordinate reference system into this international system, as it is this that permits the integration of observations with systems such as GPS into national mapping.

It is an aim of geodesy to determine the complex shape of the Earth and the coordinates of key reference points on it. The uses of the data so obtained are manifold. Geodesy may be used in geophysics or plate tectonics to infer information about the distortions of Earth’s crust from time series of observations. It may be used in oceanography, to reveal differences between the mean sea-level surface and the geoid, thereby aiding in our understanding of ocean currents. It may also be used to establish a coordinate reference frame for mapping. The previous examples cited relate very much to the modern era of space geodesy; the mapping application is one that was traditionally carried out with the triangulation techniques described above (the results of which may still form the basis of the coordinate system) but that is increasingly being established by modern satellite geodesy. In the latter case, computations are largely carried out in simple geocentric Cartesian coordinate systems, and then the results are converted into latitude and longitude in an ellipsoidal system. In the traditional methodology, the ellipsoidal coordinate system was the fundamental system, and computations of coordinates had to be carried out within it. This engendered a branch of mathematical geodesy that has largely been superseded in the satellite era and is now only required in specialist applications such as the determination of international boundaries.

Finally, mention may be made of the science of map projections, a subject that lies somewhere on the boundary between geodesy and cartography. This is the branch of mathematics that deals with the conversion between ellipsoidal
coordinate systems and representations of Earth’s surface in two dimensions for mapping and display purposes.

In conclusion, geodesy is a diverse subject that has grown from being historically closely linked to mapping and surveying into a modern science concerned with direct measurement of many of the key defining characteristics of the planet—its shape, size, deformation, and rotation. As such, it is a key component of many of the Earth sciences and is vital for a real understanding of many current concerns such as climate change.

Jonathan Iliffe

See also Altitude; Cartography; Datums; Earth’s Coordinate Grid; Geocoding; Geocomputation; Geometric Correction; Geosensor Networks; Global Positioning Systems (GPS); Latitude; Longitude; Map Projections; Surveying

Further Readings

GEOGRAPHICAL IGNORANCE

Media reports periodically highlight an appalling lack of public geographical knowledge, particularly in the United States. The National Geographic/Roper Public Affairs 2006 Geographic Literacy Study revealed that two thirds of Americans between 18 and 24 years of age were unable to find Iraq on a world map, almost half could not identify India, and three quarters could not locate Iran or Israel. Seventy-four percent of respondents selected English (rather than Mandarin Chinese) as the world’s most widely spoken primary language. Knowledge of the United States itself was shown to be equally scanty, with fewer than half of the respondents able to identify the states of New York or Ohio. Perhaps most worrisome was the finding that most young Americans remained satisfied with their ignorance. Fewer than 30% of those surveyed thought it necessary to know the locations of countries figuring prominently in the news.

Previous National Geographic/Roper surveys revealed that the United States is particularly beset by geographical ignorance. In the 2002 effort, which examined Canada, France, Germany, Britain, Italy, Japan, Mexico, Sweden, and the United States, young Americans came in second to last, beating only Mexican students. Respondents in all other countries surveyed more accurately estimated the population of the United States than did American students. Much evidence indicates, however, that geographical illiteracy is by no means limited to the United States. In an extensive 1995 survey based on sketch maps, Thomas Saarinen and Charles MacCabe found that American university students performed at
GEOGRAPHICAL IGNORANCE

roughly the global average, trailing Europeans but outperforming many others.

Unfortunately, a disregard for essential geographical distinctions extends to the highest levels of the American body politic. In the 2008 presidential election, candidates from both major parties embarrassed themselves with serious geographical gaffes. The Democratic vice presidential candidate Joe Biden erroneously alleged that the United States had expelled Hizbullah from Lebanon, while the Republican presidential candidate John McCain confused Sunni and Shi’ite Islam. More worrisome were accusations from campaign insiders that the Republican vice presidential candidate, Sarah Palin, could not name the three members of the North American Free Trade Agreement and was unaware that Africa is not a country. Although these assertions were challenged, public interviews revealed that Palin had a meager understanding of international relations and global conditions.

The current lack of concern for geographical knowledge in the United States represents a reversal from historical norms. Before World War II, secondary school students were expected to gain a close familiarity with the basic contours of the world map. To be sure, American isolationism and notions of national exceptionalism militated against the broad acquisition of global knowledge, but educated individuals—and certainly candidates for national office—were expected to be geographically literate.

Ironically, just as the United States found itself embroiled in global geopolitics in the post–World War II period, systematic geographical education was dismantled at the primary and secondary levels. Technological optimists naively assumed that advances in transportation and communication would erase the distinctions among different places, thus rendering geography irrelevant. At the same time, restless progressive educators concluded that geography was simply too stodgy and factually intensive. As a result, the subject yielded its place to an amalgam of history, sociology, and political science called social studies. In a 1993 study, J. Chiodo showed that most preservice social studies teachers in the United States lacked even a basic understanding of world geography.

The postwar period also witnessed a massive retreat from geographical instruction at the university level. Harvard University eliminated its geography department in 1948, and as Harvard led, others followed, eventually including Yale, the University of Michigan, and Columbia University. In several cases, university administrators concluded that geography was insufficiently theoretical to serve as a course of college instruction. Partially in reaction, geographers devised ever more abstract approaches to their subject matter during the quantitative revolution. This movement yielded impressive intellectual dividends, but its more extreme forms tended to disregard factual knowledge, thus perpetuating geographical illiteracy from within the discipline. Geographical ignorance negatively affects a variety of decision makers’ actions, including voting, corporate and military strategy, diplomatic efforts, tourism, and international trade.

While basic geographical instruction has been reinstated at many elementary and secondary schools in the United States, the situation remains discouraging. Without systematic instruction—from kindergarten through college—in the specific, complex, multidimensional spatial relationships that generate geographical patterns, geo-ignorance will remain the norm.

Martin W. Lewis

See also Geography Education

Further Readings


The geographical imagination is a way of thinking about the world and considering the relative importance of places and the relationships between “our” places and “other” places. The term encompasses a variety of meanings, including individual mental images and socially produced discourses about cultures, spaces, and differences. How people see the world is influenced by many factors, including social class, education, and personal and political philosophies. The particular moments in history in which people live also play a major role in how they view the world around them.

Derek Gregory explains that the geographical imagination plays a significant role in shaping much of the world’s social and spatial thought. Through the geographical imagination, people (both individually and collectively) develop a sense of boundaries, which separate “our” spaces and places from other spaces and places. Geographical imaginations are thus central to the social and spatial constructions of identity. However, few people take the time to contemplate on these issues and think them through thoroughly. The geographical imagination thus forms a part of taken-for-granted everyday assumptions, perceptions, and expectations. Sometimes people gain facets of their geographical imagination through travel, the media, or by sharing travel stories; most people gain the earliest parts of their geographical imagination through what they learn in school about other places. More important, people learn where they fit into the world that they perceive; this is the essence of the geographical imagination. Throughout history, as the particular discourses and social narratives about how the world is structured have been changing so have geographical imaginations.

This entry examines three broad examples of the geographical imagination: (1) the British imperial imagination; (2) manifest destiny and its relation to the American geographical imagination; and (3) Cold War fears in the U.S. geographical imagination.

### The British Imperial Geographical Imagination

Empires thrive, in part, because of the geographical imaginations that sustain them. One important way in which geographical imaginations are represented is through maps. The geographer Denis Cosgrove, among others, examined the role of maps in the formation of Western views of the world during the Renaissance and the Enlightenment and the ways in which they gave some groups a commanding view of the world, that is, a perspective “from above” that integrated the planet’s diverse spaces into a coherent whole. Cartography played a major role in structuring the geographic imaginations of European colonial powers. During the years of colonization, for example, many British colonials referred to the British Empire as the set of places “where the sun never sets.” This belief was an important part of the British colonial geographical imagination and was reinforced through world maps in which Britain’s colonies were often shaded red.

The British took great pride in their knowledge of the world, but like their maps, their knowledge was colored with the air of superiority and domination. In turn, this knowledge of the world was used to reinforce pride in the empire. Literature, religion, and the social and natural sciences (e.g., social Darwinism) were often closely mingled with imperial discourse. Figure 1, subtitled “God Save the Queen!” shows the relationship between knowledge and the British imperial imagination. Queen Victoria is surrounded by icons of the empire, including the banners of “Commerce,” “Literature,” and “Science.” Each of these banners justified British colonial superiority in the British geographical imagination.

The British colonialists sincerely believed that they were spreading civilization around the globe. The high costs paid by the colonized peoples were not considered. Often, they were grouped into political administrative districts that forced them to compete for resources against other colonized peoples, and families were often broken up. These historical effects still affect many former colonies today. In the British imagination, it was considered an honor to be a part of the empire, even in a subservient role like that of the colonies.

Technology also fueled the British imperial imagination. Many took great pride in the telegraph and its role in connecting the empire by easing communication and the transmission of world news. The British geographical imagination of this time focused out toward the world.
and the far reaches of the empire. News reports from abroad transmitted via telegraph reinforced imperial pride, but they also lent an aura of objectivity to British imperial control while legitimizing and naturalizing the empire.

Technology gave the appearance of a unified empire, but in reality, the empire was far from a single unified totality. The colonial subjects had diverse cultures and histories, and they experienced colonialism differently. Some peoples, such as those in India, were looked on more favorably than others, such as the indigenous Australians, who were often considered to be subhuman and were frequently exterminated violently. All colonized peoples, however, were used to further British interests. Two mutually exclusive ideas were held in the British geographical imagination. On the one hand, the diversity of peoples and places was lauded, propping up the British imperial identity. On the other hand, the British assumed a bond of unity throughout the empire, giving all its servants a common mission. The geographical imagination can gloss over or even ignore differences or ignore other peoples altogether.

**Manifest Destiny in the U.S. Geographical Imagination**

It bears repeating that geographical imaginations are perceptual and cognitive discourses; they ideologically sustain and justify actions that make reality conform to what is seen in the imagination, linking the “real” to the planned, hoped for, expected, and fantasized. Americans have also had various geographical imaginations throughout their history. Manifest destiny is one such example. Popular during the 19th century, Manifest destiny was the belief that the United States would ultimately extend from the Atlantic to the Pacific, a notion grounded in deeply rooted views of
American exceptionalism. This view shaped the geographical imaginations of many American settlers, who moved to the “empty” West to claim and tame the land. The numerous tribes of Native Americans, who had their own cultures and worldviews, did not fit conveniently into the American geographical imagination of manifest destiny. For example, Americans viewed the West as empty and unused land. Many Native American tribes, though, considered it their home. The American interior was thus not “empty” land, despite the fact that it was commonly portrayed that way, but was populated by diverse groups of inhabitants. Through brute force and violated treaties, the United States coerced the Native Americans into smaller and smaller lands and reservations.

The word imagination may seem harmless, as if it were some dreamy, impractical idea without material consequences, but geographical imaginations are far from innocent; rather, they are profoundly political and have powerful social and spatial impacts. Geographical imaginations simplify the knowledge of places by making complex and conflicting realities seem simple, with sharp lines of differentiation between one social group and others, often justified on racist, ethnocentric, or nationalist grounds. Thus, the extermination and removal of Native Americans from Western lands made the acquisition of their territories fit better with the doctrine of manifest destiny. According to the popular American historical narrative, the country was a place for immigrants to get a new start in life. In the early 20th century, the United States became popularly known as “the great melting pot.” However, this notion did not include Native Americans, whose connections to the continent long predated the Europeans. The narrative of manifest destiny was an important part of the American geographical imagination, which viewed westward expansion as a positive and necessary thing. The motives for expansion were often hidden or justified by narratives that stressed nationalism, racism, or religion; in reality, profit motives and the desire for land contributed greatly to westward expansion, but the American geographical imagination stressed the inevitability of expansion rather than the motives for it and the ensuing conflicts.

Cold War Fears and the American Geographical Imagination

Another important example of the changing American geographical imagination occurred with the Cold War, during which the United States and the Soviet Union were the world’s two superpowers. In the geographical imaginations of many Americans, the world was conveniently divided into countries that were free and democratic and those that were oppressed by communism. In the American geographical imagination,
the USSR was a drab and repressive place. During the 1980s, President Ronald Reagan dubbed it the “evil empire.” The Soviet Union, held to be dark, poor, oppressive, and stagnant, was the antithesis of America, which viewed itself as dynamic, wealthy, and free. Accusing enemies of being evil and vile is a common tool in the geographical imagination, which is often deeply moral as well as political in nature.

Such concerns were particularly acute in an age when nuclear missiles could come with little warning and deliver mutually assured destruction, with the threat of violent death looming over both superpowers. During the early years of the Cold War, school children were taught to “duck and cover,” to drop and get under a desk or table to protect themselves from nuclear blasts. Fallout shelters were another means of safety. Threats were global in scale, but safety, it was thought, could come in the smallest of scales. The purpose of discussing the Cold War in terms of the geographical imagination is not to dismiss or belittle Cold War fears but to show that imaginative geographies play an important role in how people think about the world.

Fear of nuclear annihilation was just one aspect of the American geographical imagination during the Cold War. Another fear involved the domino theory, according to which nonallied countries would successively turn communist, and then their neighboring countries would fall, like lines of dominos, into the sway of communism. Many Americans feared that communism would spread in this way throughout southeast Asia from China, Korea, and Vietnam and westward toward India. The domino theory was not limited to southeast Asia but was also used to justify the use of American military force in Central America. With Cuba already viewed as a communist threat, the concern was that Central American countries would follow its lead, bringing communism successively closer to the United States, as suggested by the domino theory. In the geographical imagination of the time, the exaggerated fear that communism would overcome Central America, and eventually Mexico, made the Soviet threat seem all the more urgent and made it imperative to prevent the spread of communism in the region. That is not to say that Americans were unified in their fear of Central America. There was much debate on the effects and justification of U.S. military and economic interventions in countries such as Panama, Honduras, and Nicaragua.

Conclusion

The geographical imagination continues to play a role in many common geopolitical and social beliefs. With the increasing speed of travel and communication, and thus increasing interconnectedness, geographical imaginations are as important today as ever. Some, such as Thomas Friedman, believe that the world is “flattening,” that is, spatial differences are becoming eradicated or reduced to the point of trivia—and thus proclaim the decline of geography as an important factor in global commerce, trade, investment, communications, and other forms of interaction. However, the belief that the world is flattening is itself an aspect of the neoliberal geographical imagination. British imperialists likewise believed that the world was connected and, like Cecil Rhodes, asserted that it was connected by the British Empire. Proponents of manifest destiny believed that America was destined be connected from coast to coast and ignored Native American claims to the land. Cold War fears of nuclear war and communism were based on the view that the world was connected through a network of mutually assured destruction. Conversely, other geographical imaginations portray contemporary global connectivity in terms of the “global village” of communications networks or cosmopolitan webs of mutual obligations.

Geographical imaginations deeply shape people’s views of other places, and thus of themselves. These views are expressed through a multitude of actions, such as political behavior, military strategy, investments, choices of tourist destinations, consumer choices, and attitudes toward immigrants and foreigners. Geographical imaginations are interwoven with a knowledge of other places, even if such knowledge is inaccurate or misleading. It is important to consider where people get their views of the world, what forms of knowledge they choose over others and what they ignore, who benefits from that knowledge, and who is left out or ignored.

Jessey Gilley
See also Colonialism; Cosgrove, Denis; Discourse and Geography; Domino Theory; Ethnocentrism; Eurocentrism; Globalization; Identity, Geography and; Imperialism; Orientalism; Other/Otherness; Photography, Geography and; Positionality; Race and Empire; Race and Racism; Representations of Space; Sense of Place; Situated Knowledge; Symbolism and Place; Time-Space Compression; Vision and Geography

**GEOGRAPHICALLY WEIGHTED REGRESSION**

Most statistical techniques assume that relationships are constant over space (the assumption of spatial stationarity). Geographically weighted regression (GWR) is a statistical technique that allows relationships to vary spatially within a study region (it therefore allows spatial non-stationarity). The relaxation of the stationarity assumption in regression has proven to be effective in modeling many spatial processes. This entry summarizes the conceptual and mathematical background to GWR.

### Background

Regression analysis, in various guises, is without much doubt the most popular form of statistical analysis practiced. Its popularity arises because it allows researchers to quantify the relationship between two variables while accounting for (holding constant) the potentially confounding relationships between other variables. This is an extremely useful feature that can be employed in a wide variety of application areas. In a linear framework, these relationships can be represented with the following general model:

\[ y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_n x_{ni} + \epsilon_i, \]  

where \( y_i \) is the value of the dependent variable observed at location \( i \); \( x_{1i}, x_{2i}, \ldots, x_{ni} \) are the values of the independent variables observed at \( i \); \( \beta_0, \beta_1, \ldots, \beta_n \) are parameters to be estimated; and \( \epsilon_i \) is an error term that is assumed to be normally distributed.

Within this model, researchers are interested in obtaining accurate estimates of the parameters \( \beta_0, \beta_1, \ldots, \beta_n \), which inform them of the nature of various statistical relationships that in turn can be used to infer aspects of the determinants of variation in the dependent variable \( y \). The parameter estimates obtained in the calibration of such a model are obtained from the following estimator:

\[ \beta^* = (X^T X)^{-1} X^T Y, \]

where \( \beta^* \) represents an estimate of \( \beta \).

To make clear what is happening here, multiple observations on each of the variables \( y, x_1, \ldots, x_n \) are needed to obtain a single estimate of each parameter in the model. It is impossible to determine any set of estimates based on a single observation of \( y, x_{1i}, x_{2i}, \ldots, x_{ni} \) since then an infinite number of parameter values would fit the equation exactly. Consequently, researchers have to estimate the parameters in the model...
statistically from multiple observations of the variables $y, x_1, x_2, \ldots, x_n$ and the more observations they have on each of the variables, the more reliable their estimates become as representatives of the true relationships within the model, ceteris paribus.

The question then is where do these data come from? If the data are time series, then multiple observations of $y, x_1, x_2, \ldots, x_n$ can be obtained at the same location and a regression run for that location (while taking into account serial autocorrelation issues). If the data are spatial (i.e., one has observations at multiple locations), then an estimate of the parameters in the model can be obtained by pooling the data from the various locations at which the data are recorded within a study area. Obviously then, the parameters that are estimated in the regression analysis represent averages of the relationships that exist in each of the locations at which the data are recorded. This is the method by which regression is performed in spatial analysis, and two potential problems arise that are unique to spatial data (although equivalent problems surface in aspatial data).

One of these potential problems is that of spatial dependency in the data, whereby the relationships being estimated by the parameters in the model are not independent (a likely scenario with spatial data), and this leads to problems of inference given that the framework for this assumes that independent data are used to estimate the parameters. This topic is covered in Fotheringham, Brunsdon, and Charlton (2002) and is not the subject of this entry.

The other potential problem is that of spatial nonstationarity (also referred to as spatial heterogeneity), whereby the relationships being estimated by the parameters in the model are not constant over space. In this case, taking the averages of the processes at different locations (how regression with spatial data works traditionally) will lead to biased parameter estimates that do not give any indication of the spatial variation in the processes that generated the data used in the calibration of the model. In this case, describing a spatially nonstationary process with a single parameter estimate would be akin to describing the intricate spatial variation in temperature or rainfall across the United States with a simple average value. Although researchers would never dream of doing the latter (they would naturally want to describe the spatial variation in temperature or rainfall on a map), they routinely report average parameter estimates from regression performed on spatial data without thinking of whether or not that average is hiding some very important spatial variation in the processes they are investigating.

So how can researchers investigate potential spatial variations in relationships when they typically have only one set of observations on $y, x_1, x_2, \ldots, x_n$ at each location within a study area? As stated above, multiple observations of each of the variables are needed to obtain an average set of parameter estimates. GWR does this by defining a location at which a local regression will be performed and then weighting the observed data by the distance each data point is from the regression point, with data locations in closer proximity given more weight than data points farther away (see Figure 1). This regression point is then moved across the study region. Each time this is done, a local regression is performed on the weighted data, generating a set of local parameter estimates (see Figure 2).

### Operationalizing Geographically Weighted Regression

The geographically weighted version of the regression model described in Equation 1 is

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_n x_{in} + e_i,$$

where $i$ refers to a location at which data on $y$ and $x$ are measured. In this case, it also depicts locations at which local estimates of the parameters are obtained, but the two sets of locations need not be the same. It is perfectly feasible to obtain local parameter estimates at locations where no data on $y, x_1, x_2, \ldots, x_n$ exist (see Figure 3).

On the basis of the notation in Equation 3, the estimator for the local parameters is

$$\hat{\beta}(i) = (X'W(i)X)^{-1}X'W(i)Y,$$

where $W(i)$ is a matrix of weights specific to location $i$ such that observations nearer to $i$ are given...
greater weight than observations farther away. The matrix \( W(i) \) has the following form:

\[
W(i) = \begin{pmatrix}
    w_{i1} & 0 & \cdots & 0 \\
    0 & w_{i2} & \cdots & 0 \\
    0 & 0 & w_{i3} & \cdots \\
    \vdots & \ddots & \ddots & \vdots \\
    0 & 0 & 0 & \cdots & w_{in}
\end{pmatrix}, \tag{5}
\]

where \( w_{in} \) is the weight given to data point \( n \) when the estimates of the local parameters are being derived for location at location \( i \). The weighting functions tend to be Gaussian or Gaussian-like, reflecting the nature of many spatial processes, and the results of GWR appear to be relatively insensitive to the choice of weighting function. However, the results will be sensitive to the degree of distance decay in the weighting function, so that it is necessary to determine an optimal distance decay value by examining the goodness of fit of the local models using different bandwidths.

**Bandwidth and Scale**

The bandwidth in whatever weighting function is selected in GWR is clearly an important operator. It controls the degree of localization of the resulting parameter estimates: A large bandwidth relative to the size of the study region implies only a broad regional variation in relationships (or no spatial variation); a small bandwidth relative to the size of the study region implies considerable local variation in processes (see Figure 4). Hence, the optimal bandwidth is an indicator of the scale
Figure 2  The process of geographical weighting
Source: Author.

Figure 3  Geographically weighted regression undertaken at locations where no data exist
Source: Author.
The optimal bandwidth in a GWR calibration results from a trade-off between bias and variance of the local parameter estimates. Too small a bandwidth leads to a large variance in the local estimates because of the relatively small number of data points that will be used in the local calibration. In the extreme case, as the bandwidth approaches 0, the local model will wrap itself around the data, so that only the local intercept will have a nonzero estimate that will be equal to \( y_i \), and the remaining parameter estimates will all be zero. In this case, the number of parameters in the local model is equal to the number of observations, \( n \). Conversely, too large a bandwidth leads to large bias in the local estimates because data are drawn from locations farther away from the regression point. Ideally, researchers would like to have repeated observations at the same location so that they can calibrate separate models for each location, but this is rarely possible, and hence, they have to “borrow” data from the surrounding locations. The farther away they “borrow” data from, the more bias they introduce into the local parameter estimates. As the bandwidth approaches \( \infty \), the local model will tend to the global model as all the local estimates will be based on the same data set and the number of parameters will equal \( k \), the number in the global model.

For all practical applications of GWR, the bandwidth will be greater than 0 and less than \( \infty \), and the effective numbers of parameters in the resulting GWR model will lie between a minimum of \( k \) and a maximum of \( n \), depending on the bandwidth. This number need not be an integer and is referred to as the effective number of parameters (ENP). Although it may seem strange that the ENP estimates in a GWR calibration is not necessarily an integer (indeed, it will rarely be an integer), a little thought demonstrates why this is the case. Suppose a global model is calibrated using data distributed across a region (the traditional application of regression analysis to spatial data) and the number of parameters estimated in the calibration of this model is \( k \). Furthermore, suppose the region is divided into two and the same model is calibrated separately for both subregions. The number of parameters then estimated is \( 2k \). Similarly, if the region is segmented into three areas and the model calibrated separately for each of the three distinct regions, the number of parameters estimated is \( 3k \), and so on. Now suppose that the same model is calibrated by GWR in this region and there are \( n \) data locations at which the model is calibrated. Shouldn’t the number of parameters estimated then be \( nk \)? Strictly speaking, the answer is yes—we do have \( nk \) parameter estimates, but this is not what the formula for ENP measures. The formula measures the equivalent number of independent parameter estimates—that is, the number of parameter estimates that would be generated if the samples of data on which the estimates are based were independent (as in the example where the region was separated into distinct areas). In GWR calibration, one is not separating the data into distinct regions where the data are only used once to produce one set of parameter estimates. The same data will be used in the calibration of parameter estimates at different locations, albeit with different weightings in each of the location regressions, depending on the location of the data points with respect to the location of the regression points. Consequently, GWR parameter estimates for the same relationship but produced for different locations are not independent of each other; the degree of dependency will depend on how close the regression point locations are to each other. The ENP thus measures the equivalent number of independent parameters estimated in a GWR calibration, and this will always be between \( k \) and \( n \) and will rarely be an integer.

Applications

As of January 2010, the number of Google references to GWR was more than 109,000 and was increasing exponentially. The number of applications of GWR to social, health, and environmental data is now huge and increasing with each month. The technique has proven to be popular in a wide variety of application areas in academia, government agencies, and the private sector. There are several reasons for this popularity.

First, there is now a selection of software for GWR that makes it very easy to apply the
technique to almost any form of spatial data. The most well-known perhaps is GWR 3.0, the software supplied from the National Centre for Geocomputation at the National University of Ireland Maynooth, which is described elsewhere (Fotheringham et al., 2002). A new version of this software, GWR 4.0, which includes the facility to run mixed GWR models, is due to be released soon. Others include the GWR module in the Environmental Systems Research Institute’s (ESRI) ArcGIS 9.3; the GWR module in R; the SAM ecological software package; Terra-seer’s version; and a Stata version from Mark S. Pearce.

Second, the technique can be applied to almost all spatial data sets in which a form of regression relationship can be established. As long as some model can be established of the type shown in Equation 1 and the coordinates of the data points are known, then a geographically weighted version of this model can be formulated. In practice, however, some problems might be encountered in obtaining sensible GWR results. The most common of these are as follows:

- Too few data points for sensible GWR calibration: GWR is a “data-hungry” technique. It is difficult to define a precise minimum number of observations needed for GWR, but recognizing that each local regression needs to have a sufficient number of data points with a reasonable weight to make the estimated coefficients reasonably reliable suggests that GWR should not be performed when there are fewer than 150 data points. Even with this size of data set, only very broad regional trends in relationships can be observed; data sets with more than 1,000 observations are generally needed to have a chance at uncovering fine-scale spatial variations in relationships.

Figure 4  Spatial weighting functions and bandwidths
Source: Author.
• Data that are spatially isolated or separated by large areas over which no data are recorded, such as a string of island communities: To reduce excessive bias in the local parameter estimates, GWR needs data in relatively close proximity to each regression point. Having data spread out over large distances creates excessive bias.

• Data that have relatively little local variance: Recall that GWR is essentially a series of local regressions and each local regression needs to conform to the usual regression requirements, including having sufficient variation in each variable. A common problem occurs when a GWR Poisson or binary logit model is calibrated and the dependent variable is either a count or a binary variable. In such cases, locally it might be that all the values of the dependent variable are 0, so that a local regression cannot be run.

• Other problems that affect global regression will also affect local regressions—GWR is not a panacea for all ills. Indeed, because the local regressions use only a small sample of the overall data set, problems can be compounded in some local regressions while being ameliorated in others.

• Starting with a poor global model: GWR is not a magic formula that corrects poor global model specification. It is very important to start with as good a global model as possible and only then perform GWR to examine for possible non-stationary relationships. Where relationships are strongly nonstationary, there will be impressive improvements in goodness of fit, but some improvements can be spurious, especially if the global model is a poor one to start with. Under such conditions, as mentioned above, the local model can simply wrap itself around the data, creating the misleading impression of increased understanding of the processes underlying the creation of the observed data.

A third reason for the popularity of GWR is that the results of GWR, because they are geocoded, lend themselves to visual interpretation and to further spatial analysis. Instead of having a single parameter with which to represent a relationship between two variables, researchers now have a surface of such values that can be mapped in a variety of ways and subjected to further spatial analysis. For instance, it is possible to create pseudo-three-dimensional surfaces, interpret a whole new geography—that of relationships rather than variables, and ask questions that were previously unthinkable. Why is a particular relationship significantly positive in some areas but significantly negative in others? Why do some areas exhibit similar relationships? Are there regions where sets of different relationships seem to exhibit similar patterns? All these questions are only possible when researchers view the output from local, rather than global, models. Of course, not only local parameter estimates can be mapped, but output from GWR researchers can also map local standard errors, local goodness-of-fit measures, and local t values; indeed, any diagnostic from global regression has a local equivalent.

Conclusion

GWR is a simple yet powerful statistical technique for uncovering spatial variations in relationships. While certainly not all relationships are expected to vary over space, it seems reasonable to assume that some might. For instance, in hedonic price modeling, spatial variation in the supply of some attribute that affects house prices would suggest that the effect of that attribute on house prices would vary spatially: In areas where the attribute is relatively scarce, its effect on house prices would be greater than where it was plentiful.

GWR thus allows us to examine potential spatial variations in relationships and consequently allows us to examine a whole new geography. It prompts us to ask questions we would not normally consider, and it brings the role of space and spatial diversity very much to the fore in statistical analysis. It is a quintessential spatial statistical technique having as inputs spatial data, applying a spatial weighting function to the data, and producing geocoded outputs that can be mapped.

A. Stewart Fotheringham

See also Fotheringham, A. Stewart; Quantitative Methods; Spatial Autocorrelation
GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) are a specialized category of information systems, in which data and information have an explicit spatial component given by location. A GIS comprises data, software, hardware, people, and operational procedures. GIS does not exist in a vacuum, it is always a part of a larger information infrastructure, where it fulfills specific functions aimed at responding to users’ information needs. The users of geographic information involve public organizations, such as local, regional, and national governments; private companies; and individual members of the public. Since much of the information generated by GIS is used to support decision making, GIS have been sometimes referred to as spatial decision support systems. GIS share a core set of functions enabling spatial data input, storage, editing and management, data analysis, visualization, and report generation. Traditionally, GIS have been centralized and operated by GIS professionals, responding to the information needs of end users. With the proliferation and advancement of networking and Web-based technologies, a parallel (to the centralized) model of GIS has emerged, in which software engineers and GIS professionals develop geographic information (GI) Web-based services and GI-savvy users access the services using proliferating points of network access.

Application domains of GIS are numerous and include diverse areas such as disaster and hazard management, retailing, homeland security, crime prevention and community policing, environmental management, city planning, regional development, transportation programming, logistics, construction management, public health and epidemiology, and natural resource development.

Piotr Jankowski

See also GIS, Environmental Model Integration; GIS, History of; GIScience; GIS Implementation; GIS in Archaeology; GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Land Use Management; GIS in Local Government; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; GIS Software; GIS Web Services; Spatial Analysis; Spatial Decision Support Systems

Further Readings


GEOGRAPHY EDUCATION

Geography education is a teaching and research subfield focused on educational purpose, practice, and theory in geography, from prekindergarten through the postgraduate life span, in both formal and informal contexts. Though much of the
research in geography education has tended to investigate problems in kindergarten through Grade 12 (K–12) curriculum and instruction, since 2000 there has been a noticeable trend toward research activity exploring teaching and learning issues in higher education, especially in the areas of spatial cognition, computers and multimedia, graduate education, and faculty development.

**Geography in Elementary and Secondary Education**

During the past two decades, geography has made considerable progress in the American school curriculum, having gained a discernible presence apart from social studies and a growing cadre of teachers skilled in modern analytical concepts and technologies. Improving the quality of geography teaching and learning in American education was the focus of a national reform movement that dates back to the early 1980s and that marshaled the talents of some of geography’s leading scholars and professional organizations. In 1984, the Association of American Geographers (AAG) and the National Council for Geographic Education established a Joint Committee on Geographic Education to publish Guidelines for Geographic Education, a document that informed teachers, school districts, local and state education authorities, and the general public of the importance of geography in K–12 education through the use of “five fundamental themes” and associated learning activities. Since its publication, more than 100,000 copies of the Guidelines have been disseminated in the United States. This period also witnessed the establishment of the state geographic alliances, a network of organizations whose primary purpose is to promote collaboration between university geographers and inservice teachers. The majority of these alliances were established during the late 1980s and early 1990s, with grants from the National Geographic Society to set up an alliance in each state. Most of these alliances are still actively in operation, in many cases funded through endowments that were matched by the National Geographic Society and other organizations.

Perhaps the crowning achievement of the geographic education infrastructure building during the 1980s was the designation of geography as one of five core subjects under the National Education Goals, formulated by the National Governors Association in 1990 and set into law by the Goals 2000: Educate America Act of 1994. The Goals 2000 Act prompted geographers to develop national standards for K–12 teaching and learning, published in 1994 as Geography for Life: The National Geography Standards. By 2004, geography was present in the curriculum standards of every state except Iowa. Although the reform movement was successful in raising the status of geography in American education, it has yet to make significant headway in raising student achievement and teacher preparation in the subject. The 2001 geography assessment by the National Assessment of Educational Progress (NAEP) found that more than two thirds of American students in Grades 4, 8, and 12 did not meet proficient competency standards. This situation is likely to continue until concerted efforts are made to reform the pedagogic content knowledge of geography teachers, especially at the preservice stage of the professional continuum.

Another noteworthy development since 2000 has been the increase in enrollment for the advanced placement (AP) course in human geography. The number of high school students taking AP human geography grew from 3,272 in 2002 to 28,239 in 2007. An updated version of the national geography standards will be published in 2010. The next NAEP geography assessment is scheduled for 2010.

**Geography in Postsecondary Education**

Geographers have also dedicated a considerable amount of effort to the improvement of teaching and learning in higher education. Some of the earliest efforts in this regard include the AAG’s Commission on College Geography, established during the 1960s to focus on faculty development and instructional issues in undergraduate education. It published an extensive paper series on the teaching and learning of geography and, during the 1970s, initiated a number of professional development programs to promote innovative practice in curriculum and instruction, including the Commission on Geographic Education and the Teaching and Learning in Graduate Geography projects.
During the 1980s, an informal effort known as the Phoenix Project, led by some of geography’s most influential scholars, was successful in providing support and networking for another cohort of early-career geography professors. The Committee on the Status of Women in Geography has a substantial record of organizing conference sessions to address career issues for women graduate students and faculty. Since 2002, the AAG has supported two broad-based initiatives to enhance career preparation in geography. One of those is the Geography Faculty Development Alliance (GFDA), funded by the National Science Foundation (NSF) between 2002 and 2007 and since institutionalized by the AAG to provide early-career faculty with the theoretical and practical knowledge needed to succeed in their careers of research, teaching, and service. Complementing and extending the GFDA is Enhancing Departments and Graduate Education (EDGE) in Geography, a research and action project funded by NSF to examine issues affecting the professional development of master’s and doctoral students in geography programs.

Since the mid 1990s, geographers have also pursued a wide range of federally funded projects in undergraduate education, including the Core Curriculum in GIScience (geographic information science) and Core Curriculum in GIS (geographic information systems) for Technical Programs, the Geographer’s Craft Project, the Virtual Geography Department Project, Hands-On: Active Learning Modules on the Human Dimensions of Global Change project, and the AAG Center for Global Geography Education project. Many of these projects have explored strategies to internationalize teaching and learning. In 1999, an International Network on Learning and Teaching Geography in Higher Education was formed with the aim of building an international community of geographers dedicated to collaborative teaching and research on postsecondary education issues.

Undergraduate degrees in geography awarded by U.S. institutions of higher education grew by about 66% (from approximately 2,900 to 4,800) between 1987–1988 and 2003–2004. During that same time period, master’s degrees in geography grew by about 33% (from approximately 580 to 770), and doctoral degrees grew by about 33% (from approximately 150 to 200). Much of this growth coincided with the discipline’s broader recognition in scientific and academic communities and the increased demand for geographically skilled professionals in the workforce, particularly in the area of GIS technology. A recent NSF report, *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century*, presented a 10-year outlook for environmental research and education and cited geography as a key source of concepts and technologies to synthesize research questions and data acquisition across spatial, temporal, and societal scales. In 2004, the U.S. Department of Labor and U.S. Department of Education listed GIS technology as one of the three most important emerging areas for job growth alongside nanotechnology and biotechnology.

*Michael Solem*

See also Education, Geographies of; Geographical Ignorance; National Council for Geographic Education

**Further Readings**


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The term *geolibrary* was introduced in 1998 by the geographer Michael Goodchild to explicitly identify an emerging class of digital system, the “library filled with georeferenced information,” as an important element of the growing global spatial data infrastructure. The geolibrary concept grew out of efforts at organizing and providing shared access to the digital holdings of map...
libraries and spatial data repositories. These collections typically include scanned paper maps, satellite imagery, aerial photographs, and geographic information systems (GIS) data files. A key distinction was drawn between this “geographical information,” as representations of the surface and near surface of the Earth, and the vastly broader category of “georeferenced information,” defined as any information referring to or about particular places.

A geolibrary indexes its holdings by location, specified by one or more place names and a geographic “footprint” of any complexity, as well as by the traditional library catalog keys of title, author, and topic. Many digital map libraries and spatial data clearinghouses are then by definition geolibraries, in that their holdings may be browsed and searched by location. It became increasingly apparent that the methods developed for accessing those data could be applied to any digital information objects associated with locations specified by name or footprint. In principle, any library would become a geolibrary if its holdings were comprehensively georeferenced. At its furthest extension, such functionality resembles the Digital Earth vision of systems providing access to all available digitized information related to any specified location.

Geolibrary development—particularly as distributed systems—has raised numerous research challenges and is a valuable context for their solution. These include the following: (a) interoperability for data sharing by means of metadata standards, authority lists, and ontologies; (b) gazetteer development, that is, the association of a particular spatial footprint with potentially numerous place names; (c) efficient spatial indexes for databases and related issues of scale, resolution, and generalization; (d) georeferencing, including the parsing of textual material for named places and related temporal issues; (e) spatiotemporal query algorithms; and (f) interface usability for spatial browsing and search informed by cognitive principles. Significant incremental progress in all these areas has made the prospect of very large, distributed geolibraries increasingly realistic.

In 2004, Goodchild suggested that the next stage of progress in geolibrary development might be from simply delivering information objects (maps, imagery, and other documents) to adding some ability to open and process those objects. In addition to answering the basic query “What do you have about this place?” it could answer many of the type “What is (or was) so interesting about this place?” Such extensions are likely to blur distinctions between the geolibrary and other emerging classes of information systems, including digital atlases and georeferenced digital encyclopedias.

Karl Grossner

See also Gazetteers; Geocoding; Goodchild, Michael; Interoperability and Spatial Data Standards; Spatial Data Infrastructures

Further Readings


GEOLOGIC TIMESCALE

The geologic timescale divides the 4.5-billion-year history of Earth into unequal divisions of time. Originally, these divisions were based on sedimentary rocks and their corresponding fossils. Each time interval has its own unique fossil assemblage, and the boundaries between many intervals of geologic time correspond to mass extinction events. The most famous of these was at the boundary between the Mesozoic and the Cenozoic eras. At that time, land-dwelling dinosaurs became extinct, likely due in part to the impact of a large asteroid near the present-day Yucatan Peninsula.

The intervals of the geologic timescale are hierarchic—eons include eras, eras include periods,
### Geologic Timescale

<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Epoch (Cenozoic only)</th>
<th>Age (Millions of years)</th>
<th>Major Biological &amp; Geologic Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENOZOIC</td>
<td>Quaternary</td>
<td>Holocene (Recent)</td>
<td>.01</td>
<td>Ice Age begins and evolution of modern mammals; man reaches N. A.; general uplift of continent.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pleistocene</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>Pliocene</td>
<td>5.5</td>
<td>Evolution and Development of major mammal groups; Cascadian Orogeny in northwestern United States; in latest Cenozoic, Eocene lake system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Miocene</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oligocene</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eocene</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paleocene</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>MESOZOIC</td>
<td>Cretaceous</td>
<td></td>
<td>130</td>
<td>Extinction of dinosaurs; flowering plants flourish; height of Cordilleran Orogeny.</td>
</tr>
<tr>
<td></td>
<td>Jurassic</td>
<td></td>
<td>185</td>
<td>First birds, dinosaurs and mammals continue to evolve; beginning of Cordilleran Orogeny which formed the Rocky Mountains.</td>
</tr>
<tr>
<td></td>
<td>Triassic</td>
<td></td>
<td>230</td>
<td>Conifers evolved; first dinosaurs; first mammals; Appalachian Orogeny; some orogeny in Cordillera.</td>
</tr>
<tr>
<td></td>
<td>Permian</td>
<td></td>
<td>265</td>
<td>Archaic reptiles and mammal-like reptiles evolve. Appalachian Orogeny.</td>
</tr>
<tr>
<td></td>
<td>Pennsylvanian</td>
<td></td>
<td>310</td>
<td>First reptiles; cool swamps formed; beginning of the Appalachian Orogeny.</td>
</tr>
<tr>
<td></td>
<td>Mississippian</td>
<td></td>
<td>355</td>
<td>Expansion of amphibians; much carbonate deposition; Antler Orogeny in Cordilleran Mobile Belt (Rocky Mountain area).</td>
</tr>
<tr>
<td></td>
<td>Devonian</td>
<td></td>
<td>413</td>
<td>First land plants; first jawed fishes, sharks and bony fish; amphibians appear; Acadian Orogeny in the Appalachian belt.</td>
</tr>
<tr>
<td></td>
<td>Silurian</td>
<td></td>
<td>425</td>
<td>Jawless fishes evolved; much reef development; evaporite mineral development.</td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td></td>
<td>475</td>
<td>First vertebrate remains known from this time; Taconic Orogeny in Appalachian belt.</td>
</tr>
<tr>
<td></td>
<td>Cambrian</td>
<td></td>
<td>600</td>
<td>First shelled invertebrates; major flooding of North America.</td>
</tr>
</tbody>
</table>

Precambrian time began 5 billion years ago.

**Table 1** Geologic timescale

*Source: National Park Service.*
and then periods are divided into epochs. Epochs can be further subdivided into stages. In developing the geologic timescale, geologists frequently relied on the law of superposition, which states that younger sediments were deposited on top of older sediments. Thus, by applying this principle to a single exposure, one can determine the relative sequence of events visible in the geologic record. Unfortunately, only a small part of the entire expanse of geologic time is recorded in one place, either because the older parts of the record are still buried or because much of the record has been destroyed by erosion. Thus, the geologic timescale was created by combining records from many different places using the process of correlation, where the relative ages of rocks in different areas are determined, often by matching the fossil species they have in common. Most of the periods in the currently accepted geologic timescale were named by the 19th-century European geologists, and they were frequently named after the places where the rocks are exposed. For example, the Devonian Period was named by Adam Sedgwick and Sir Roderick Impey Murchison after Devonshire, England. In discussing geologic time, geologists distinguish between the time intervals themselves (geochronologic units) and the rocks deposited and formed during those times (chronostratigraphic units). So the Devonian Period, a geochronologic unit, is now represented on Earth by the rocks of that age, referred to as the Devonian System, a chronostratigraphic unit.

One unfortunate outcome of the patchy record of Earth’s history is that geologists working in different areas have at times developed separate and incompatible versions of the geologic timescale. Such disputes are resolved by the International Commission of Stratigraphy (ICS). In one recent case, many Russian scientists used the term Vendian for the interval of time between 632 and 542 mya (million years ago), while many Australian scientists used the term Ediacaran instead. Arguments were made for both names, and in 2004, the ICS decided on the Ediacaran Period, which is now a part of the internationally recognized geologic timescale.

Although the law of superposition and the use of fossils in correlation allowed for a relative geologic timescale to be developed, throughout the 19th century, the durations of geologic time intervals, the age of their boundaries, and the age of the Earth were speculative. This changed shortly after the discovery of radioactivity by Henri Becquerel in 1906, and by 1913, Arthur Holmes published the first geologic timescale with absolute ages determined by isotopic abundances as a result of radioactive decay. In addition to the well-known method of carbon-14 dating applied to organic material, many rocks include radioactive isotopes whose rates of decay are exceedingly slow (e.g., $^{238}$U [uranium], $^{147}$Sm [samarium], $^{187}$Re [rhenium]). By using radioactive isotopes with low rates of decay, scientists have determined that some meteorites are 4.5 billion yrs. (years) old and record the composition of the early solar system.

Although the age of some volcanic rocks can be determined using radioactive dating, the same cannot be done for nearly all sedimentary rocks, the very places where much of Earth’s geologic history is recorded. Thus, areas where volcanic rocks, such as ancient lava flows or ash falls, are interbedded with sedimentary rocks are particularly important for adding absolute ages to the geologic timescale. Much of the timescale for the past 65 million yrs. has been developed using two additional sources of data to interpolate between known ages: paleomagnetism and cyclic stratigraphy. Earth’s magnetic field has undergone numerous reversals during geologic time, so that at some times in Earth’s history a compass would have pointed south, while during others it would have pointed north, like today. These magnetic reversals have been recorded in many sedimentary rocks and also in the volcanic rocks that make up the oceanic crust. As new crust cools, it acquires a copy of Earth’s magnetic field. Old crust is pushed away from the midocean ridges as new crust forms, causing a series of stripes of north-pointing oceanic crust alternating with south-pointing oceanic crust. The development of new oceanic crust at midocean ridges occurs at a fairly constant rate, thus the widths of the magnetic stripes on the ocean floor are directly proportional to the actual durations of each direction for Earth’s magnetic field.

In places where sediment is continuously deposited, cyclic patterns in the layers deposited may develop in response to climate change. In some
cases, these climatic changes can be tied to subtle yet important changes in Earth’s orbit called Milankovitch cycles, after the Serbian astrophysicist Milutin Milankovitch. The three most prominent Milankovitch cycles occur in periods of 24, 40, or 100 ky (kiloyears, or thousand years). The periods of these cycles are remarkably regular, and by counting cycles back through the geologic record, the precision and potentially the accuracy of some events can be determined within 40,000. Again, no such continuous record exists, so it requires many separate geologic sections to be correlated for this process of “orbital tuning.” These more precise dates have been extended back to 34 mya, and will likely be extended back to 75 mya in the near future. Although further refinements in the geologic timescale are expected, changes for the ages of most boundaries will be on the scale of less than 2 mya.

Jonathan Henry Geisler

See also Geomorphology; Plate Tectonics

Further Readings

International Commission of Stratigraphy: www.stratigraphy.org

Geomancy

The mantic arts employ diverse mediums for purposes of divination. Geomancy (geo- for “Earth,” -mancy for “divination”) is the mantic art that divines earthy, terrestrial, or telluric mediums to discover hidden knowledge and/or predict the future. Geomancy literature and its applications constitute the oldest continually practiced scholarly geographic tradition in the world. East Asian variants of geomantic applied arts have had major impacts in shaping some of the world’s most populated cultural landscapes during ancient and medieval times.

The two major exemplars of geomancy in human history are the “African” (or Western) “science of sand” and the “Chinese” (or East Asian) “wind-and-water” variant, popularly known as feng shui (various spellings). Geomantic configurations divined in both systems relate to celestial phenomena. The Islamic variation of African geomancy, which interprets geometric designs formed by casting pebbles, diffused through the Byzantine and Latin worlds across Europe and into England, to gain popularity during the medieval and Renaissance periods. The telluric medium divined in East Asian feng shui geomancy is terrain itself. Due to its preoccupation with landform divination, feng shui is known alternatively in English as topomancy and terrestrial astrology. Esoteric ideas related to correspondences and reciprocities between Earth and heaven as human habitat are highly symbolized and deeply embedded in feng shui theories and applications. Feng shui surveying in the field involves skill, intuition, instrumentation (principally its complex astrobiological model and compass), and cartographic skills.

Feng shui geomancy, aptly described a century ago by Herbert Chatley, is the art of adapting the residences of the living and the dead so as to cooperate and harmonize with the local currents of the cosmic breath. Motivating the effort are expectations of propitious outcomes for nature and humanity. Where feng shui surveys are diagnostic and remedial, skilled surveyors are perceived to be “Earth doctors.” Two distinct traditional schools of feng shui—“landscape” and “compass”—are discernable, but their skills seem complementary and overlapping. The mass popularity of Chinese geomancy reached its pinnacle under the Qing dynasty (AD 1644–1911) but then faded dramatically throughout East Asia wherever modernization and communism became entrenched. However, among the unforeseen impacts of economic liberalization and globalization over the past few decades is the unexpected
new demand throughout East Asia for traditional feng shui skills, services, and products.

Related to this resurgence, and even more remarkable, is the diffusion to and sudden growth and persistence of a popular wave of interest in Asian geomancy throughout the West, and especially in the United States. This trend has had some major economic impacts in high-end residential and commercial West Coast real estate markets, meanwhile generating a variety of geomancy-related “New Age” products and services in mass markets nationwide. Higher-education programs, including those in geography, planning, and Africana studies, have meanwhile increasingly incorporated the topic of geomancy into their curriculums.

David J. Nemeth

See also Cultural Geography; Cultural Landscape; Landscape Interpretation

Sources of Geometric Distortions

Geometric distortions are typically classified into (a) internal distortion resulting from the geometry of the sensor and Earth rotation or curvature characteristics and (b) external distortions resulting from the attitude of the sensor or the shape of the object. Geometric distortions can be divided into systematic (predictable) source of the error or nonsystematic (random). Internal errors include errors of skew, scanning system, and relief displacement. External errors include altitude alterations and attitude changes (roll, pitch, and yaw).

Methods and Procedure

Some internal distortions are predictable or systematic and are generally corrected at the ground station or by image vendors. There are two types of correction: (1) image-to-map rectification and (2) image-to-image rectification. In the image-to-map rectification, a map (with correct projection) is used to correct images and convert them into a planimetric system. This method should be used when area, direction, or distance measurements are needed after correction. Image-to-image correction involves matching the coordinate systems or column-and-row systems of two digital images. In this case, both images should cover the same geographic area.

The general procedure involves (a) registration: selecting ground control points (GCP) and image pixel coordinates (row and column) with their map coordinate counterparts (e.g., meters northing and easting in a UTM [Universal Transverse Mercator] map projection); (b) spatial interpolation (also called transformation): identifying the geometric relationship between input coordinates and output coordinates; and (c) intensity (or pixel value) interpolation (also called resampling): determining the pixel value of the output image from the input image. For the registration, GCPs can be easily identified on the imagery and located accurately on a map (e.g., road intersections, lake edges, river junctions). For spatial interpolation, the paired coordinates (i, j and x, y) from many GCPs (e.g., 20) can be modeled to derive geometric transformation coefficients. These coefficients
are then used in polynomial equations for computing root mean square error (RMSE). RMSE ideally is to be within 1 pixel. For intensity interpolation, new values are assigned in one of three ways: (1) nearest neighbor, (2) bilinear, and (3) cubic.

Sunhui Sim

See also Coordinate Systems; Coordinate Transformations; Image Registration; Radiometric Correction; Spatial Interpolation

Further Readings


GEOMETRIC MEASURES

A great variety of measures, many still in their early development, are used to describe the geometric properties of an object/distribution in geographic space. Some are derived directly from geometry, such as length, perimeter, and area, whereas others have evolved in the study of geography, for example, the compactness index. Unlike their geometric counterparts, objects/distributions in geographic space appear complex and diverse, depending on their point composition (e.g., cities), lines (railway networks), or areas (e.g., the territory of the Philippines). Furthermore, little agreement exists among spatial analysts on the classification of the various geometric measures. The history of these measures dates to the “Common Era,” when Strabo recognized the difficulty of measuring the shape of Italy. Five categories of geometric properties are recognized in the literature: (1) centroid, (2) orientation, (3) range, (4) intensity (or compactness), and (5) shape. Centroid is the center point of an object/distribution in geographic space, the point at which the object/distribution attains balance; orientation is the direction along which an object/distribution is arranged over space; range is the two-dimensional (2D) scope (spread) of an object; intensity is the extent of compactness (closeness) among elements of an object/distribution; and shape is what is left after the effects of position, orientation, and size are removed.

Various indices are used to measure each of these geometric properties. Centroid measures include the mean center and its extensions to global coordinate systems; orientation measures include the direction of the major axis of the standard distance ellipse; range measures include the mean distance, standard distance, standard distance deviation, and standard distance ellipse; intensity measures include compactness and spatial intensity indices; and shape measures include the elongation, circularity, overlap indices, ratio of the length of the major to the minor axis of the standard distance ellipse, and others. Notably, the standard distance ellipse can show simultaneously all the five geometric properties on a map except shape; and the centroid usually serves as a reference for calculating the other geometric measures.

Enormous difficulties have been encountered in examining the geometric properties of spatial objects, including the creation of a coherent framework. It has also been difficult to separate some properties from others; for example, measures of shape, compactness, and orientation are often mixed. Furthermore, geometric properties vary with scale; for example, the length of a river increases as scale decreases. Finally, the curvature of the globe creates problems; for example, the standard distance ellipse does not apply to spatial analysis in spherical space.

These geometric measures follow to varying extents the laws of addition and transitivity. Unlike length and area, each of which are additive across spatial objects, the five categories of geometric measures are not additive. But the rule of transitivity generally applies, except in the case of the shape indices. Transitivity, for instance, increases with the levels of similarity between two shapes.

Roger R. Stough and Dennis Zhao
The geomorphic cycle was introduced by William Morris Davis as a comprehensive model of the way in which natural landscapes develop at a regional scale. Although initiated somewhat earlier, it emerged as a largely finished product in 1899 and quickly became the dominant way in which landscapes were viewed academically for several decades. While its dominance in the world of research was challenged in the late 1930s and substantially soon after World War II, it remained an important teaching framework much longer. Today, the comprehensive model is passé, but discrete elements and terms remain and are often used shorn of their original critical conceptual underpinnings.

**Context and Objectives**

The geomorphic cycle was launched into the scientific world at a time when Charles Darwin’s work was an overt and pervasive influence. The “cycle” is largely biological in tenor. However, Darwin’s concept of evolution, dominated as it is by the concept of randomness, was modified by Davis into a concept of inevitable change over time, that is, mathematical probability became deterministic. This was also the period when eustatic theory, isostasy, and epeirogeny were all in their introductory phases within geomorphology. Davis did not accept all these new ideas but clearly embraced some of them.

Davis’s objective was to develop and present a model of landscape development that was deductive and theoretical. Just how deductive Davis’s formulation of the model really was has been widely debated. Davis wanted his model to be not only theoretical but also genetic, so the model was designed both to describe and to explain landforms. He did not attempt to describe the fundamental geologic origin of landscape but rather the subsequent geomorphic development. For example, he was not particularly interested in the initial uplift of a plateau or mountain system; rather, he sought to explain its development subsequent to uplift.

**Essential Components**

Initially, Davis forwarded five controlling factors for landscape development: (1) structure,
(2) process, (3) stage, (4) relief, and (5) texture of dissection, and he also initially invoked the rate of uplift as important. However, he pruned his model vigorously, and structure, process, and stage are the three variables with which it is most widely associated. Even they are not coequal as stage was Davis’s preeminent preoccupation. Stage is a relative, not absolute, temporal concept, being the amount of time elapsed since uplift. Consequently, a landscape may exhibit different stages in different parts.

The Davisian concept of stage was widely discussed in anthropogenic terms of youth, maturity, and old age. Youth follows uplift immediately and is a period when the relative relief of the landscape (i.e., the local difference between the valley bottom and the abutting mountain or ridge tops) increases. Youth ends when all the original landscape surface has been removed by erosion; specifically, this implies that valley sides have eroded so greatly as to have removed the original summits. During maturity, the landscape attains maximum relative relief, and valleys are V-shaped. As maturity advances, the landscape becomes more rounded and the valley system more extensive and better integrated, while floodplains emerge and expand. During old age, relative relief is greatly reduced. The surface becomes gently rolling with broad valleys with floodplains, ultimately producing a plain without relief. However, Davis chose to highlight the stage immediately prior to the ultimate landscape, thus the world famous “peneplain,” which should reflect little or none of its geologic structure and bear infrequent resistant elements standing up as “monadnocks” (these are hills or mountains descriptively, but their origin is specifically derived from a Davisian view of landscape development).

The geomorphic cycle really incorporates three cycles: (1) a cycle of landscape development, (2) a cycle of river development (both individually and as networks), and (3) a cycle of slope development. The cycle of landscape development is very slow and is initiated by uplift, proceeded by erosion, and terminated by renewed uplift (this is why stage is a relative, not absolute, temporal concept). The cycle of river development has a youthful stage with few major rivers and few major tributaries but numerous minor rivers. Floodplain expansion marks mature and later stages, as well as network integration. During old age, very extensive floodplains and broad gentle slopes predominate, and generally speaking, landscape domination by fluvial processes gives way to domination by mass wasting.

Slope development is not present as a discrete focus in many of Davis’s papers; however, it emerges frequently as an element. His most important idea concerning slope development is that the slope angle declines with time. This perspective stems from two rather fuzzy and weakly integrated ideas: (1) more material is removed from the top of a slope than from the toe or bottom and (2) as particle size decreases downslope, so does the angle needed to mobilize the material. The first idea is founded on rate of removal, the second on a weathering rate. The resulting slope is sigmoidal (convexo-concave), with an upper convexity and a lower concavity. The Davisian sigmoidal slope profile has been widely debated in slope geomorphology. Basically, Davis’s notion that the upper convexity ensues from dominance by creep processes has survived; his lower concavity explanation is less satisfactory. The universal validity of the sigmoidal slope profile has been hotly debated; for example, it was explicitly rejected by Lester King, who viewed it as a degenerate slope form. The matter was frequently debated also in terms of specific climatic zones, with the Davisian profile usually being categorized as widespread in temperate, as opposed to tropical, environments.

A number of other salient components of the geographical cycle merit separate identification and discussion because the cycle became so pervasive that for many years virtually all English-speaking geomorphologists discussed landscape development exclusively within its framework. A very important reality is that the geographical cycle and “denudation chronology” fitted one another hand in glove. Denudation chronology is a view of landscape development that reconstructs it as a series of dated stages, although the dating was usually only relative and/or extremely broad (this was an era prior to isotope dating). While denudation chronology predated the geographical cycle in origin, the two became inseparable for decades.

Davis infused geomorphology with a welter of “morphogenetic terms,” the overwhelmingly majority of which were part and parcel of the
geographical cycle. A morphogenetic term is a single word that incorporates a description of the shape of something (the “morpho-” component of the word) while also purporting to explain its origin (the “genetic” component of the word). For example, a peneplain is a gently rolling eroded landscape, with occasional erosional remnants upstanding (i.e., monadnocks [another morphogenetic term]), that is the penultimate stage of the geographical cycle. It is not just a near-flat erosional surface but one specifically produced by progression of the geographic cycle. To draw the illustration even more explicitly, a Davisian peneplain, with monadnocks, is a fundamentally different intellectual view of landscape and its development from King’s pediplain, with inselbergs, bornhardts, or koppies (there is terminological overlap among these latter three terms, all of which are essentially erosional remnants). The Davisian landscape has been lowered and is essentially temporally all of one age, while the Kingian landscape is of necessity time-transgressive given its mode of development, which is by the parallel retreat of slopes.

Davis took up the long-used concept of “grade” and transformed it in a fundamental manner. Grade, essentially an equilibrium concept, is of very old origin and was originally used to designate a time-independent balance between a stream’s energy and its erosive and transporting power. What Davis did was to take a time-independent term and make it time dependent, that is, developed over time. So grade was absent in rivers during youth, acquired during maturity, and maintained thereafter. Grade was attained first at a river mouth and advanced upstream, producing a smooth concave longitudinal profile to the river. This profile was anchored by the ultimate base level (sea level) overall but might also be anchored locally, for example, a lake. River grade became a major issue in fluvial geomorphology. Davis invoked a parallel grade concept and applied it to slope development. Here, decreasing particle size was also invoked as an explanatory factor for decreasing slope angle, hence a lower concave slope profile. However, there was no reason to expect slope and river grade to emerge in the landscape at one and the same time.

On a related, but essentially independent, note it is worth appreciating that Davis was a remarkably skilled sketch artist. The quality of his sketches, read explanatory diagrams, provided support for his argumentation in what amounted to a second language. Of course, sketching has the inbuilt advantage of being editorial in and of itself.

**Criticisms of the Cycle**

In essence, the initial criticism of the geomorphic cycle came from Davis himself. The idea was launched as a universal concept, that is, one unconstrained by climatic variability; however, it took Davis only a few years to appreciate that a model of cycle development in the temperate mid-latitudes would need substantial modification if it were to be used in other climes. Consequently, Davis added to his concept of a “normal” or mid-latitude climate a version of landscape development in an arid climate; other special cases were subsequently forwarded by disciples of his views. In many ways, this need can be viewed as the birth of climatic geomorphology.

The most pervasive problem with the geographical cycle rests in the manner in which Davis himself pursued and proselytized it. A model of landscape development is essentially a hypothesis; as such, it needs to be tested against empirical evidence, that is, landforms and landscapes. However, Davis took his model as an established and/or foolproof explanation of landscapes and then proceeded to see landscapes exclusively in terms of that model. Where real landscapes failed to substantiate his expectations, he invoked special circumstances of numerous kinds. A simple example would be the frequent invocation that a peneplain had been warped subsequent to its initial formation. Given his immensely influential position at Harvard University and in the geomorphological community at large, his cause was also taken up by influential disciples. It seems reasonable to assert that because Davis did not pursue process geomorphology vigorously, those who challenged him and later geomorphologists tended to do so. In turn, the pursuit of process geomorphology necessitated much greater attention to detail and direct measurement; consequently, process geomorphology came to function at the slope scale rather than at the regional scale. Consequently, much of Davisian geomorphology has
been bypassed by contemporary process geomorphology, some portions of it having been demonstrated to be wrong, while other portions are deemed irrelevant. Some large-scale modeling in recent years has suggested that the geographical cycle contains important truths, but it is no longer a model that carries much credibility with the majority of geomorphologists. Nevertheless, it should be seen as a towering, pioneering effort that shaped geomorphology both by what it aspired to do, a lengthy period of disciplinary domination, and by the enormous intellectual effort that was required within the discipline to oppose and overcome it.

Colin Edward Thorn

See also Davis, William Morris; Geomorphology; Gilbert, Grove Karl; Penck, Walther; Physical Geography, History of

Further Readings


Geomorphology is the science that studies landforms, including their shape (morphology) and spatial distribution (location and position in the landscape), the materials of which they are composed (bedrock, soils, sediment), and the processes that form, maintain, and change them over time. Geomorphology has long been recognized as a major subfield of geography and geology, but in recent decades, concepts and techniques from geomorphology have been applied widely in engineering (e.g., restoration of damaged streams), ecology (e.g., estimating fish abundance as a function of physical habitat features), forestry (e.g., evaluating the stability of hillslopes), agriculture (e.g., modeling soil erosion), hydrology (e.g., assessing flood hazards, finding groundwater), archaeology (e.g., reconstructing past environments), pedology (e.g., explaining the movement of heavy metals, relative age dating of geomorphic surfaces using soils), space science (e.g., landforms on Mars), and environmental planning (e.g., evaluation of geomorphic hazards such as dust storms, coastal erosion). Many opportunities exist in geomorphology to share concepts and techniques with practitioners in other branches of physical geography (“integration”) and in human geography (“synthesis”). Geomorphology is an intimate part of the emerging, interdisciplinary field known as Earth system science, a scientific approach to describe, explain, and predict biogeochemical phenomena at or near the surface of the Earth. A significant number of geomorphologists practice Quaternary geomorphology, the reconstruction of past environments. This part of geomorphology has received new vigor in light of the need to predict the effects of climate change, a task that profits from the ability to decipher past adjustments between form and process.

On the one hand, geomorphology is a basic science in that it seeks to understand the diversity of landforms without necessarily having any direct implications for human activities. On the other hand, geomorphology is an applied science because concepts and techniques from geomorphology are applied to practical problem solving in engineering, resource evaluation, and environmental planning.

Geomorphologists study landforms on a variety of spatial scales, ranging from regional/continental (e.g., stream networks, mountain building) down to microscopic (e.g., development of soil crusts, cosmogenic dating of earth materials). A reductionist approach, which relies on principles from physics and chemistry, has proven useful in explaining small-size phenomena, for instance, in
understanding the factors that affect the initial movement of an individual particle by wind or water. However, for larger-size phenomena, probabilistic modeling approaches have provided more explanatory power. What is ordered and regular at one spatial or temporal scale may be disordered and irregular at another scale. Some exciting new developments in mathematical modeling in geomorphology have emerged from the application of complexity and chaos theory.

Geomorphologists rely on an amazing array of field methods for the collection of primary data, supplemented by secondary data sources: topographic maps, digital elevation models, land surveys, soil surveys, geologic maps, aerial photography, satellite imagery, and numerical dating techniques. Data are also collected in laboratory settings with physical models (e.g., wind tunnels, flumes) and lab analyses of soil and sediment samples (physical-chemical analyses, dating). Data are analyzed using geographic information systems, computer simulation models, and geospatial statistics.

### History of Geomorphologic Thought

To understand geomorphology requires an examination of how fundamental, guiding ideas in geomorphology changed over time. The discipline of geomorphology was not recognized as a distinct subdiscipline of geology and geography until the 19th century, but early writings on landforms can be traced to classical Greek, Roman, Arab, and Chinese scholars. For example, Herodotus is attributed with the observation that “All Egypt is the gift of the Nile,” a recognition that the fertility of floodplain soils depends on annual floods, more specifically the deposition of silt and leaching of salts. Herodotus also believed that the sea level had changed over time. Aristotle believed that stream erosion was a dominant process in forming landscapes. Strabo found that the size of river deltas depends on the drainage area, the resistance of the source rock, and the erosional strength of tides.

During the European Renaissance, contributions were made by Leonardo da Vinci, among others. Leonardo used glass flumes to study stream erosion, transport, and deposition. However, much of his work was not published until the 18th century. The Church exerted powerful control over academic thinking at this time, so scientists had to reconcile their scientific observations with religious orthodoxy. During the 17th and 18th centuries, theories of landform development focused on catastrophic processes of origin, including sea-level change (Abraham Gottlob Werner), floods (William Buckland, Adam Sedgwick), vulcanism (e.g., Horace-Bénédict de Saussure), and endogenic processes (e.g., John Phillips).

The concept of uniformitarianism came to dominance in the 18th century and persisted until the mid 19th century. This concept is generally attributed to James Hutton, although it was his colleague, John Playfair, who popularized Hutton’s ideas in a book published in 1802. By the mid 1800s, geomorphology was coined as a new word and was often taught under the name physiography. Western literature was dominated by uniformitarianism in the writings of Charles Lyell and the Frenchman Jean Baptiste Perrault; Georges-Louis LeClerc, Comte de Buffon; and Nicolas Desmarest. In the late 19th century, the concept of uniformitarianism was modified into the term gradualism, which allows for the changing rates of geomorphic processes over time (Andrew Crombie Ramsey, Ignaz Venetz, Jens Esmark, Louis Agassiz).

In the late 19th century, geomorphology was given renewed attention thanks to the detailed explorations of the Western United States by John Wesley Powell, Grove Karl Gilbert, and Charles Dutton. Powell classified streams by their relation to the geologic structures they cross—an idea that has stood the test of time. Gilbert conducted lab experiments on sediment transport and wrote on a wide range of geomorphic topics: intrusive igneous landforms, fault scarps, Pleistocene lakes, craters on the moon, barrier islands, glaciers, and more. Gilbert is attributed with several key concepts that persist to this day: the graded stream, lateral planation, stream competence, the origin of pediments, controls on drainage patterns, and the effects of geologic structure. Dutton’s studies of the Grand Canyon region are legendary for a number of reasons, not the least of which are the spectacular drawings of the Grand Canyon by William Holmes that were included in Dutton’s U.S. Geological Survey publications on the region. Dutton also recognized evidence in the field for
old erosion surfaces, which he said could be subject to uplift and new episodes of erosion.

The first half of the 20th century was dominated by William Morris Davis and his disciples (Eliot Blackwelder, Charles Cotton, Oscar Diedrich von Englyn, Nevin Fenneman, Armin Kohl Lobeck, J. Hoover Mackin). Based on deductive reasoning, and extending the earlier work by Powell and Dutton, Davis developed the “cycle of erosion” to characterize landscapes as progressing through stages of youth, maturity, and old age, until rejuvenated by uplift. The Davisian cycle was popular at first because it was simple, ordered, unified, and harmonious. However, it quickly came under criticism in Europe, notably by the German geomorphologist Walther Penck. The German Herbert Louis Büdel and the Frenchman Jean Tricart promoted climatic geomorphology as an alternative. Davisian concepts were replaced in the latter half of the 20th century by empirical, quantitative geomorphology (Robert Horton, Arthur Strahler, William Rubey, Luna Leopold, M. Gordon Wolman), the systems approach (Richard Chorley, Stanley Schumm), and a focus on human impacts. The development of new techniques, notably in the field and with remote sensing, led to an emphasis on direct measurement of processes. Specialties developed within geomorphology based on the dominant process being studied: tectonic, volcanic, fluvial, glacial, periglacial, aeolian, coastal, weathering, mass movement, karst, and biogeomorphology.

Geomorphological research is currently published in a variety of journals, but most notably in several that are dedicated to the discipline: Geomorphology (since 1987), Earth Surface Processes and Landforms (since 1976), Journal of Geophysical Research-Earth Surface (since 2003), and Zeitschrift für Geomorphologie (since 1957). Geomorphologists in the United States are affiliated with the American Geophysical Union, Association of American Geographers (AAG), Geological Society of America (GSA), and International Association of Geomorphologists. Incidentally, Davis was the first president of both the AAG and the GSA. Geomorphologists from multiple disciplinary backgrounds have come together each fall since 1970 for the Binghamton Geomorphology Symposium, which highlights a different theme every year.

The most fundamental concept in geomorphology is that landforms develop as the result of the interplay of the resisting framework, driving forces, and time. The resisting framework refers to the effects of lithology (differential resistance to weathering and erosion), stratigraphy (layered sequence of lithologic units), structure (geometric arrangement of geologic units—strike and dip, faults, folds, joints, etc.), and vegetation (e.g., soil-binding effect of roots, roughness caused by vegetation on wind and water). The driving forces in geomorphology include endogenic processes (diastrophism, volcanism), exogenic processes (weathering, erosion transport, and deposition), and extraterrestrial processes (impact of asteroids and meteorites). It is perhaps more prudent to state that geomorphologists pursue their studies by examining the spatial distribution of the resisting framework and driving forces over time.

Recent developments in techniques to provide absolute dates of landforms have provided a new impetus for the discipline of geomorphology. Several forms of radioisotope dating are available to date earth materials over a range of timescales, depending on the materials available. For example, $^{14}$C (carbon) is used to date carbon-bearing materials back to about 40,000 yrs. (years); $^{40}$K (potassium) is used to date potassium-bearing materials from approximately 20,000 yrs. old to the oldest rocks on Earth. Dating with cosmogenic isotopes and optically stimulated luminescence (OSL) are two rapidly developing, lab-intensive methods. Cosmogenic isotope dating is based on the accumulation of in situ, stable, radioactive isotopes in rocks that have been bombarded by cosmic radiation. Cosmogenic isotopes accumulate over time on exposed rock surfaces, thus providing a means by which the surface can be dated, subject to a number of constraints. The most often used isotopes are $^{36}$Cl (chlorine), $^{10}$Be (beryllium), and $^{26}$Al (aluminum), which can provide ages back to 500,000 to 1 million yrs. OSL dating is based on the absorption and storage of radiation in the form of electrons trapped in the impurities and defects of mineral crystals. Dating is related to the last exposure of a mineral to sunlight prior to being buried. Other breakthroughs
with dating landforms have occurred with fission track dating, paleomagnetism, obsidian hydration dating, dendrochronology, and lichenometry.

Geomorphologists focus on time in another regard. When examining the adjustment between landforms and processes, it is meaningful to compare the time between major disturbances to landforms (natural or human) with the time required for landforms to adjust to the disturbance. It is typical for a reaction (lag) time to exist between the disturbance and when the landform begins to adjust. Then the adjustment toward a new equilibrium will begin and span a period of time known as the “relaxation time.” If the major disturbances are spaced over an interval of time greater than the response time (reaction + relaxation time), a new equilibrium can be achieved. If, however, the next major disturbance occurs before the completion of the response time, equilibrium cannot be achieved. Thus, it is possible for some landforms to achieve a dynamic equilibrium, whereas other landforms may never achieve equilibrium.

Geomorphology is a key element in separating environmental change due to human activities from change that would have occurred without human interference. Journal articles and textbooks abound that describe the impact of humans on the delicate adjustment between landforms and geomorphic processes, through the effect of forestry, agriculture, grazing, mining, urbanization, wildfires, military maneuvers, dams, channelization, climate change, and more. Roger L. B. Hooke estimated that worldwide humans move 45 Gt (gigatons; 1 Gt = 10^9 tons = 10^{12} kilograms) of earth materials each year. This compares with rivers (14 Gt/yr. excluding human effects + 39 Gt/yr. from meander migration = 53 Gt/yr.). Glaciers move 4.3 Gt/yr. at present, compared with 10 Gt/yr. during the Pleistocene. Hillslope processes move 0.6 Gt/yr.; waves move 1.24 Gt/yr.; wind and volcanoes together move 1.0 Gt/yr. Mountain building moves 14 Gt/yr. on continents and 30 Gt/yr. in the oceans.

Jonathan Phillips has proposed that geomorphologists recognize that the development of landforms is controlled by a combination of global factors (i.e., independent of time and place, governed by the laws of physics and chemistry) and local factors. Each landscape has an inherited history—from biophysical and human influences—which will almost certainly vary from place to place. The historical legacy of local disturbances leads to increased divergence in landform development, while global controls lead to convergence. One approach, therefore, is to increase the generality of models, concepts, and research in geomorphology and to reduce the number of variables and factors considered, while others continue to seek deterministic models to describe landscapes in all their complexity.

In his book *To Interpret the Earth: Ten Ways to Go Wrong*, Stan Schumm has described the factors that confound geomorphologists as they seek to interpret landforms:

**Time**: Whether a landform can be considered to be in equilibrium depends on the time frame over which observation occurs.

**Space**: The difficulty in explaining geomorphic phenomena increases as the size of the phenomenon increases; and the length of time needed for a geomorphic feature to adjust is directly related to the size of the feature.

**Location**: It is difficult to extrapolate cause and effect from one location to another.

**Convergence**: Similar landforms can be created by different initial combinations of processes and materials.

**Divergence**: Different landforms can be created from similar initial combinations of processes and materials.

**Efficiency**: Explanations of cause and effect may be confused by nonlinear relationships.

**Multiplicity**: A single explanation will rarely provide total understanding; it is likely that multiple cause-and-effect linkages are operating to create geomorphic phenomena.

**Singularity**: A large natural (and unexplained) variation exists between similar geomorphic systems.

**Sensitivity**: Geomorphic systems vary in their sensitivity to disturbances. Some systems have thresholds of change, where perturbations (in form or process) up to a certain level produce no change but after that threshold value is exceeded, rapid change begins.

**Complexity**: Geomorphic systems can respond to a disturbance in opposite ways at different times or places.
Geographers offer three special insights in geomorphology. First, the mixed methods and theories that geographers employ—quantitative and qualitative, post-positivist science and social theory, muddy-boots fieldwork linked with geographic information science (GIScience)—together position geographical geomorphologists to resolve the debate over human-triggered change in landscapes and to explain the frequent disconnect between geomorphology, policy making, and resource management. Second, many problems in geomorphology require training, experience, and expertise in understanding coupled physical-human systems. Third, modern techniques of measuring the rates of geomorphic change help place the human factor in perspective and explain the spatial variability of natural hazards.

Richard A. Marston

See also Atoll; Barrier Islands; Biota and Topography; Carbonation; Coastal Erosion and Deposition; Davis, William Morris; Dunes; Faulting; Fieldwork in Physical Geography; Fjords; Folding; Geologic Timescale; Geomorphic Cycle; Gilbert, Grove Karl; Glaciers: Continental; Glaciers: Mountain; Gully Erosion; Hydrology; Impermeable Surfaces; Karst Topography; Landforms; Landslide; Periglacial Environments; Permafrost; Physical Geography, History of; Plate Tectonics; Powell, John Wesley; Rill Erosion; Rivers; Sedimentary Rock; Sedimentation; Soil Erosion; Volcanoes; Wind Erosion

Further Readings


Geophagy, literally “earth eating,” also known as pica (technically the consumption of all inappropriate materials), is the practice of consuming dirt, typically clays. Geophagy may be practiced for either health or religious reasons. Devout Christians and Muslims have engaged in ritualized forms of geophagy for centuries, typically in the form of wafers ostensibly derived from holy sites.

Geophagy was widely practiced in many pre-industrial societies, particularly in tropical environments and most commonly by pregnant women to relieve the nausea of pregnancy. Through trial-and-error experimentation, many cultures learned to compensate for nutritional deficiencies of trace minerals or vitamins, particularly sulfur, zinc, calcium, phosphorus, potassium, magnesium, and manganese, by consuming certain forms of clay. Consumption of dirt rich in iron is helpful in regions where people suffer from iron deficiency due to the high prevalence of hookworm disease. Soil may be added as well when salt or calcium are deficient in the local diet (especially among non-milk-drinking peoples), or kaolin may be added as an antidiarrheal or gastric disorder treatment, especially for infants. Some Native American tribes, as well as Sardinians, mixed dirt with corn or acorns to neutralize the acids. South American Indians regularly used clays for their alkaloid-binding properties when consuming bitter potatoes. When viewed in this light, geophagy is a rational nutritional adaptation to dire mineral deprivation. However, severe geophagy also carries health risks such as growth retardation and liver enlargement. When it occurs as a regularized social practice, dedicated clay pits and specialized workers are used to harvest, clean, and process the clays consumed, and they may be traded over wide areas. Geophagy is also often prevalent during times of extreme famine.

Although it carries risks of bacterial infection or parasites, in many non-Western cultures, geophagy was culturally sanctioned as healthy and beneficial. Sometimes called “calabash chalk” in much of Africa, clays were consumed by up to half of the population of pregnant or breast-feeding women, either to alleviate morning sickness...
or to improve lactation. Geophagy was imported from West Africa to the Southern United States via the institution of slavery. Sometimes known as “Cachexia Africana” in the slave-based South, geophagy among slaves was sometimes prevented through the use of mouth locks.

Despite centuries of attempts to eliminate it and increasingly severe social stigmatization, geophagy persisted in the South. White clay consumption was traditionally confined mostly to impoverished rural black women and children (although some whites too practiced it). A survey in 1942 in Mississippi found that 42% of schoolchildren regularly consumed clays. Sometimes other materials such as starch, chalk, or ash were substituted for clay. Although widely discredited as a practice of poor people (and today, as an eating disorder), in some locales it was institutionalized, and baked or processed clays and dirt are occasionally still found in the South today. Migration from Africa to former colonial countries introduced geophagy into Britain and France.

See also Food, Geography of

Further Readings


Origins of the “Science” of Geopolitics

In the earliest phases of its scholarly history, geopolitics was taken up with great interest in Germany, Italy, Japan, and the United Kingdom. As a portmanteau adjective, geopolitics attracted interest because it hinted at novelty. It was intended to convey an interest in the often unremarked geographical dimensions of states and to posit “laws” in international politics based on a series of geographical facts such as the relationship between land- and sea-based powers. Informed by social Darwinism, the struggle of states and their human creators was emphasized, as was the need to secure the “fittest” states and peoples. According to Ratzel, the state should be conceptualized as a super-organism that existed in a world characterized by struggle and uncertainty. To prosper, let alone survive in these testing circumstances, states needed to acquire territory and resources.

Strikingly, in Germany after World War I, an influential figure, General Karl Haushofer, was pivotal in the creation of a journal of geopolitics in 1924. As a former aide-de-camp to Rudolf Hess and an established expert on Japan, Haushofer became professor of geography at the University of Munich. Like earlier writers such as Ratzel, he believed that German survival, let alone consolidation, in the aftermath of the 1919 Peace Conference would depend on the country understanding the geographical realities of world politics. As a defeated nation, Germany’s national boundaries had changed, and empires such as the Austro-Hungarian and Ottoman were dismantled. Europe
was in a state of flux, and the alleged scientific status of geopolitics was important in establishing intellectual legitimacy and policy relevance in Germany and elsewhere. For Germany to prosper, Haushofer opined that interwar Germany needed to appreciate five issues: (1) physical location, (2) resources, (3) territory, (4) morphology, and (5) population. If Germany was, what he termed, a “space-hopping” country rather than “space bound,” then it might be able to capitalize on all available resources and territorial opportunities. He also contended that if the world were organized into a series of pan-regions, then it might be possible for Germany and other states such as the United States and Japan to exercise global leadership. Under his global model, Germany would dominate the Euro-Asian landmass and Africa. He was a keen supporter of the proposed Berlin-Baghdad railway and of German colonies in Africa. As a consequence of his close relationship to Hess, these ideas have been credited with informing Hitler’s plans of spatial expansionism in the East and were even seen as contributing to the final solution involving Jews, communists, and others, including the disabled. While Haushofer was fascinated by spatial relationships and Germany’s reemergence after World War I, there is neither any evidence that he shared Hitler’s hatred of European Jewry nor evidence that he viewed the world as being controlled by an international cabal of Jews and communists. By the late 1930s, Haushofer’s influence was on the wane, and he thought the invasion of the Soviet Union in 1941 was a geostrategic error. He later committed suicide in 1946, after being sidelined in academic and policy-making terms.

While the relationship between geopolitical thinking and Nazism was never as clear-cut as some may have believed, it did not prevent a new generation of émigré intellectuals such as Hans Weigert, Andreas Dorphalen, and Robert Strausz-Hupe from warning American audiences about the dangers of the “science” of geopolitics. The latter was invested with great scientific potential, and popular magazines such as Reader’s Digest warned about the shadowy Institute of Geopolitics at the University of Munich. The truth was less prosaic, and German engagement with geopolitics was, in different ways, being replicated in other countries, including not only fascist Italy but also Portugal and Spain. In each case, geopolitics appears to have been popular because it offered a way of looking at the world that tied a country’s destiny to an analysis of resources, territory, and population. Maps, including those found in school textbooks, were important in communicating those ideas to both popular and scholarly audiences.

Germany’s and Japan’s defeat in 1945 had consequences not only for global geopolitics but also for the academic study of geopolitics itself. One important figure in the case of the latter was Father Edmund Walsh, Jesuit priest and American colonel, who interviewed Haushofer in the aftermath of the conflict. While Walsh was convinced that the German professor and former general should not be tried for war crimes, he described the latter as a “master geopolitician.” Although he did not blame German geopolitics for Hitler’s racist and expansionist policies, the “science” of geopolitics was damned in the eyes of many observers. A new generation of American political geographers (and their Soviet counterparts) spurned the term geopolitics and were careful to distinguish their own activities as intellectually objective and less deterministic with regard to the spatial and environmental parameters influencing states. With very few exceptions, the term geopolitics disappeared from the American academic scene and was not revived until the 1970s. Distinguished geographers such as Isaiah Bowman and Richard Hartshorne had warned their colleagues about the poisonous reputation of the subject matter.

One partial exception to this generalization was the geographer Saul Cohen, who for about 40 years has been reminding colleagues of the importance of understanding the changing global political map. Inspired by a Dutch American geographer, Nicholas Spykman, Cohen sought to convey how the onset of the Cold War made it even more important that Americans understood the geographical basis of the struggle between the United States and the Soviet Union. In his pioneering work, Geography and Politics in a Divided World, he explored how the world was composed of a series of shatterbelts and showed how the two superpowers were locked in conflicts over territory, resources, and access. He also emphasized the importance of understanding regional differences and not assuming
that the Cold War struggle against communism was occurring against a backdrop of uniform political, economic, and cultural geographical relationships.

Geopolitical Revival: The Kissinger Factor

Former Secretary of State Henry Kissinger, a German-born émigré and intellectual, has been credited with reviving American interest in geopolitics even if his use of the term was more informal than that by academic scholars. In the midst of the Cold War, Kissinger was involved with President Nixon in some highly significant geopolitical maneuvers, including negotiating a more cordial relationship with China and relative détente with the Soviet Union. The United States was also in the process of leaving Vietnam. Kissinger’s use of the term geopolitics was in part a way of coming to terms with these changes and in part to underscore the significance of global balance and permanent national interests. He was particularly mindful of the Soviet Union’s “geopolitical ambitions” and “geopolitical aspirations” with regard to the Euro-Asian landmass. The United States had to maintain its presence in the region and seek to contain its ideological challenger.

Although Kissinger’s use of the term geopolitics was often vague, it did invoke earlier writers such as Halford Mackinder, a former director of the London School of Economics and Reader in Geography at the University of Oxford, who had drawn attention to the importance of the Euro-Asian landmass (the Heartland, to use his term) before and after World War I. Although not cited by Kissinger, another leading policy figure and intellectual under the Carter administration was informed by Mackinder’s legacy. The Polish-born National Security Advisor, Zbigniew Brzezinski, was a keen advocate of geopolitics and wrote about the need to contest Soviet expansionism in the Euro-Asian landmass. After the Soviet invasion of Afghanistan, this call took on an added sense of urgency as America looked to the anti-Soviet resistance and regional allies such as Pakistan to contest the occupation. Some political analysts assert that American military and financial support throughout the 1980s not only helped defeat the Soviet war machine but also, paradoxically, created the conditions for the al-Qaeda terror network to later rely on the battle-hardened veterans in Afghanistan to carry out deadly attacks from the 1990s onward.

During the last years of the Cold War, some policy intellectuals and academics in the United States came together to establish the Committee on the Present Danger (CPD), which used geopolitics and other academic pursuits to argue that the United States needed to ditch policies such as détente and take up a more aggressive foreign policy committed to achieving victory in this titanic struggle. The Reagan administration epitomized this geopolitical worldview and committed the United States to intervening all over the world, including Central America and the Middle East, in an attempt to secure such a victory. This strategy frequently resulted in American support for dictators such as Saddam Hussein in Iraq and countless military regimes in Asia, Africa, and Latin America. The bigger geopolitical picture involved the defeat of the Soviet Union and its allies. In 1989, Eastern European socialist allies such as East Germany and Czechoslovakia folded, and the Cold War was considered terminated. Two years later, the Soviet Union collapsed, and the realist and geopolitical approaches advocated by the CPD appeared triumphant.

Toward a Critical Geopolitics

At the same time that the Cold War was entering a more confrontational phase, a new generation of geographers was preparing the ground for the emergence of a more critical engagement with geopolitics. For some geographers, this meant exploring the peace literature, and for others, it entailed an engagement with world-systems theory and a more politico-economic understanding of global capitalism. During the 1980s, political geography and geopolitics were revived in the universities. While Henry Kissinger had repopularized the term, world events coupled with 40 years of its absence from the political forum made it easier in the English-speaking world for a new generation of scholars to reclaim the term. In other parts of the world, this option was either less straightforward or simply not relevant. In the Soviet Union, for instance, the term geopolitics was
still considered to be deeply problematic and offensive. While in Latin America, scores of mainly military officers were using geopolitics with little to no apparent concern for its alleged associations with Nazism.

American-based scholars such as Gerard Toal, Simon Dalby, and John Agnew began to reengage with this controversial intellectual train, later to be dubbed critical geopolitics. Rejecting the notion that geopolitics was an objective “science,” they conceptualized geopolitics as a discourse and political practice. In other words, attention was drawn to how geopolitics is performed and the manner in which it constructs representations of the geographies of global politics. If geopolitics is a discourse capable of producing and circulating spatial understandings of world politics, then it is imperative that we consider, so they contended, the consequences of such representations. For one thing, we might explore how certain geographical understandings of Cold War America were critical not only in securing a sense of political identity (as the leader of the free world) but also in justifying a vast investment in military and technological resources (the military-industrial complex).

Since the 1990s, these writers have maintained that geopolitics can be considered to exhibit three forms: (1) a form concerned with academic manifestations of the term, (2) a practical form that involves the policy-orientated geographical templates used by presidents and prime ministers in their policy discourses, and (3) finally a popular geopolitical variety that notes how the media is central in creating and reproducing geographical understandings of local, regional, and global politics. In the case of the latter, recent research has explored how cartoons, television, films, newspapers, and the Internet contribute to the geographical socialization of citizens in the Euro-American world and beyond.

Conclusion

Geopolitics has had a varied and at times controversial history. Shunned by some, it has also been embraced by others, especially in the aftermath of the September 11, 2001, attacks on the United States when pundits and journalists embraced the term. What geopolitics offers to many is a convenient term that seems to promise a rugged respectability and a willingness to ponder the grim realities of world politics. It also frequently attracts commentators anxious to make predictions about the world, usually for the benefit of one country as opposed to others. For critical geopolitical scholars, these kinds of claims need to be scrutinized and challenged, not the least because they neglect the persistent inequalities between the North and the South, the highly gendered geographies of human security, and the environmental consequences of global political and economic patterns.

Klaus Dodds

See also Critical Geopolitics; Haushofer, Karl; Mackinder, Sir Halford; Mahan, Alfred Thayer; Nation; Nationalism; Political Geography; Ratzel, Friedrich; State

Further Readings


GeoSensor Networks

Advances in miniature, low-cost microelectronic and mechanical systems (MEMS) with limited onboard processing capabilities, storage, and short-range wireless communication links, together with the development of novel microsensors and sensor materials, enable us to build a new generation of technology that consists of large collections of tiny, untethered, battery-powered computing nodes with various sensing functions. With the continued trend toward miniaturization and the inexpensiveness of such sensor nodes, it is expected that sensor nodes will be
less than a cubic millimeter in size in the near future and that sensor networks can be made up of thousands or even millions of sensors (“smart dust”). Geosensor networks (GSNs) are a specialized application of wireless sensor network technology in geographic space to detect, monitor, and track environmental phenomena and processes at a novel spatial and temporal scale. Considering remote sensing instruments such as “telescopes,” which are commonly used to monitor environmental processes on Earth, a GSN can be viewed as an “environmental microscope” providing a spatiotemporal resolution of observations and near-real-time information never available before.

The technology of GSNs has the following constraints that pose new challenges from an infrastructure system and application development standpoint:

**Power consumption:** Sensor nodes are limited with regard to their battery supply, and energy conservation is a major system design principle. Also, communication is a much larger battery drain than local computation on a computing node.

**Low-range communication:** The bandwidth of a wireless communication link of a node is limited and its range is short. Messages from nodes at different regions of the network are typically communicated with a multihop routing strategy. Since communication energy cost is a significantly higher drain on energy consumption than the energy needed for onboard processing, optimizing and minimizing communication within the sensor network are a major system design consideration.

**Limited computing and storage capabilities:** Sensor nodes have, at least for the foreseeable future, limited onboard computational, and volatile and persistent storage capabilities. Thus, onboard data processing using the available memory and CPU capacity is also limited.

**Self-organization:** Due to the large number of sensor nodes, the vulnerability and failure rates of nodes and communication links, and the often unattended deployment, task management and handling in sensor networks need to be decentralized and self-organizing. Thus, some level of local autonomy must be provided for the devices.

Since the mid 1990s, much research in sensor networks has focused on the design of tiny computing platforms, operating systems, and programming languages for resource-constrained computing environments (e.g., TinyOS, Contiki, and nesC). A major task of GSNs is intelligent data collection and processing. Despite their powerful and novel capabilities to observe the physical world, programming sensor networks for specific observation and actuation tasks is cumbersome today due to the failure-prone nature of nodes and communication links and the vast parallel computational nature of such systems. A domain scientist interested in deploying a GSN needs to be able to define the necessary tasks in a user-friendly way and delegate the optimization and ultimately self-adaptive execution to the run-time system without having to worry about the details.

Today, it is a popular abstraction to view a GSN simply as a distributed spatial database system (DBS) with sensor nodes running tiny footprint DBS software locally, responding to queries and performing local processing and collaboration with other nodes. Each sensor node supports a single sensor table, and the attributes match the attached sensors, such as temperature, humidity, location, and so on. The query language is similar to structured query language (SQL)-style spatial queries, and it is extended with sampling epochs for continuous queries. Using this abstraction, a user can interact with the GSN as a single virtual sensor. One of the first sensor database management system prototypes is TinyDB.

Typical sensor network data collection tasks are spatiotemporal in nature. For example, a user might be interested in hourly sampled values of the light profiles around tomato plants in an industrial greenhouse to monitor and optimize the microclimate around the plants. Nowadays, spatiotemporal queries over GSNs often retrieve discrete information measured at the locations of sensor nodes. Many environmental phenomena, such as a temperature field or a gas concentration field in an open space, however, are **continuous**. The challenge exists to provide an accurate and precise estimation of all points or regions of a dynamic spatial field based on limited discrete point samples collected by the sensor nodes. Due
to the constrained nature of sensor nodes, estimation algorithms need to be lightweight and processed in a distributed, decentralized way “in the network.” Typically, streaming all sensed values out of the network to provide offline data analysis is not an option, since the raw, unprocessed data collection drains the energy resources of the network and reduces the GSN application lifetime by 90%. A valid option of data processing today is decentralized, localized event detection and decision making. For example, to detect a toxic plume, it is sufficient to detect and track the boundary of the plume, while reducing any kind of processing, sampling, and communication elsewhere in the network.

GSNs can also be deployed in a mobile way such that sensor nodes are attached to automobiles or used by pedestrians, mounted onto animals, or floating on the ocean. Here, relevant real-time sensed information is collected in a local context and only exchanged in an ad hoc way between other mobile sensor nodes currently located in the region and in (communication) proximity to each other. For example, in intelligent transportation systems, collocated sensor nodes can inform other nodes in the same region about environmental threats such as icy patches on the road or other unexpected road hazards that can be sensed on the road.

The application areas for GSNs are plentiful—for example, biodiversity, biogeochemical cycles, precision agriculture, habitat monitoring, flood monitoring, landslide monitoring, tsunami warning systems, coral reef observations, and coastal and ocean observations.

Today, a large variety of comparatively large-sized sensors with onboard processing are already in use in geographical applications. Characteristically, such sensors are stationary, expensive, and, thus, sparsely distributed over a large geographic area (e.g., a single sensor for a square-mile region). Data are logged and stored locally and retrieved in batch mode either manually or via satellite link. GSNs add the ability to monitor dynamic complex processes, at a very small and local scale, that are more difficult to observe by existing instruments due to their scale. It is, however, typical of geosensor networks that the technology is integrated with existing, larger-scale sensing platforms such as remote sensing instruments, buoys, autonomous underwater vehicles, windmills, weather stations, and so on. When combining sensor networks with the existing sensing platforms, so-called sensor webs are created. Similar to the idea of the World Wide Web, the vision is that sensors and sensor networks should be accessible and usable in a uniform way, so that scientists can find, combine, and query real-time sensors in a geographic region for a specific application. This results in the (often expensive) sensor platforms being reusable for different purposes. The Open GIS Consortium provides a standardization approach for sensor platform interfaces and data exchange (Sensor Web Specifications) for sensor webs. Today, several research networks have been established, including NEON (National Ecological Observatory Network), GLEON (Global Lake Ecological Observatory Network), CREON (Coral Reef Environmental Observatory Network), and the NEPTUNE Cyberinfrastructure.

Currently, the actual application and deployment of GSNs is in its infancy. With the increasing robustness of sensors, wireless communication, improved battery life and technology, and software developments, GSNs will become a powerful technology, an extension of the existing environmental sensing platforms.

Silvia Nittel

See also Neogeography; Remote Sensing

Further Readings

Stated simply, geoslavery occurs when a person or an institution takes control over the spatial activity of another person. The history of such control is long and has usually involved chains and walls to restrain and contain the victims. It is perhaps epitomized by the restriction of Jews to ghettos in Nazi-occupied Europe. In the early 21st century, with the advent of personal location devices such as mobile phones and global positioning systems (GPS), this control has become very personal, enabling one individual to easily monitor the location of another, control being achieved by threat or by retribution.

Tracking of individuals can be sanctioned by law and is enabled through criminal justice systems. Thus, offenders, who are released on license, can be tagged to ensure that they stick to the terms of their curfew. This has been part of offender management for a number of years. The technology to do this initially relied on a base station that simply recorded the distance the offender wandered away from the station. This approach is being replaced by GPS and mobile communication devices that report the movements of the offender and raise an alarm when the offender moves outside his or her curfew area.

Geofencing is a term used to describe the corporate use of this same technology. Many employees need to be mobile over large areas as part of their work, but employers may require them to stay within specific territories during working hours. Their locations can be monitored and alerts sounded at a monitoring office when they stray outside their assigned territories. Initially, this type of application used software to identify routes for delivery van drivers, and managers compared the recommended route with the distance driven; but this has evolved into constant

The information scientist Christoph Seifert demonstrates how to apply an electronic ankle bracelet at the district court in Frankfurt/Main, Germany, May 2, 2000. The federal state of Hesse is the first in Germany to introduce the device to control convicts under probation and house arrest.

Source: AP Photo/Frank Rumpenhorst.


monitoring of the van’s location as well as of the locations of many other mobile employees. It is known when employees take too long to traverse a road, when they speed, and for how long they stop. This issue, however, raises questions of trust and appropriateness in the workplace.

The same approach is available for child monitoring. Wristwatch-like GPS devices with mobile communications that can be locked onto a child’s wrist are available, with Web-based inspection of real-time mapping of the child’s location. Indeed, subcutaneous implanting of chips with GPS and communication devices has been suggested. Child tracking is also available through normal mobile phone systems without the GPS enhancement, although this is less accurate.

Another acceptable application of this technology is to monitor the locations of patients suffering from Alzheimer’s disease in their home or in sheltered accommodation. Devices for this application can have the additional advantage of monitoring a patient’s vital signs.

Such location services, which aim to monitor and control the location of offenders, contracted employees, children, and elderly patients, are probably socially acceptable applications of this technology. Increasing numbers of cases are coming to light, however, where the use of location services is not socially acceptable, where, indeed, they can be criminal, for instance, when the technology is applied to adults with no record of offending by those who wish to monitor their location in order to exercise control. People are using the technology for stalking others, for monitoring the location of spouses without their permission, and for checking on the locations of employees even when there is no contractual obligation regarding location.

An appropriate framework for practice of these services is essential for their control. In the United Kingdom, for example, there is a code of practice for mobile phone–based location services that states that anyone being monitored should be notified when any monitoring session starts, be notified at intervals during the monitoring, and be able to refuse the monitoring whenever they wish. Similarly, a bill was proposed to the British Parliament that would require all child-tracking services to be registered and to abide by certain codes of practice. However, it was not approved.

Geoslavery refers to all these applications, many of which are legal. However, geoslavery can also be applied in a manner that is a clear abuse of this technology. Such uses and abuses of geoslavery can be controlled through compliance with legislation and industry codes of practice.

Peter Fisher

See also Global Positioning System; Location-Based Services; Mobile GIS; Panopticon; Surveillance

Further Readings

solution. Accordingly, the first sections of this entry are devoted to a discussion of geospatial data, followed by sections about geospatial software and functionality.

Geospatial Data

**Data Production Technologies**

Geospatial data are the spatially referenced, geometric features, images, and associated attribute values that can be visualized on a hard-copy or digital map. Traditional methods for creating spatial data, such as land surveying and manual drafting and digitizing, are still practiced; however, many techniques are being replaced by automated or computer-aided data capture and processing. Remote sensing, in particular, has revolutionized the way in which many forms of spatial data are created.

Remote sensing is predominantly accomplished by means of two platforms: aerial sensors and satellite sensors. The initial product of most remote sensing instruments is a raster (a regular array of grid cells) image of Earth’s surface. By themselves, satellite and aerial imagery are critical components of most data consumers’ libraries of information. In addition, aerial imagery has become the foundation from which other data are derived. In particular, vector data (geometric features composed of points, lines, and polygons) such as roads, streams, and building footprints can often be manually or automatically digitized from imagery with greater accuracy, speed, and convenience than can be achieved by traditional methods. The advantages of raster imagery combine to make the remote sensing industry an indispensable asset to nearly all geospatial endeavors.

Another data production technology that has revolutionized the geospatial industry is the global positioning system (GPS). The GPS is, in essence, a data production technology, due to the fact that its fundamental role is to produce the coordinate location of a receiver. With the addition of differential GPS and the Wide Area Augmentation System (WAAS), receivers can yield ground coordinates within fractions of an inch of their true position. GPS satellites were initially launched by the U.S. government for military applications, and an intentional degradation of the positioning accuracy, called Selective Availability, was installed to prevent nonmilitary receivers from attaining high accuracies. Selective Availability has since been deactivated, allowing commercial and recreational receivers to achieve higher accuracies, thus enabling the expansion of the geospatial industry into the realm of location-based services (LBS), which are discussed later in this entry.

**Sectors of Data Production**

The data production sectors of the geospatial industry span private industry, government, and, increasingly, the general public. Many of the most accurate data used in production applications are created and sold by private companies. Aerial photography and national-scale transportation data, in particular, are commonly produced and sold by private companies due to the extreme costs and labor power necessary to create them. Companies such as Tele Atlas produce transportation data products with the necessary address attribute information that are sold to others, such as in-car navigation companies, for use in routing and geocoding applications.

Government agencies at the federal, state, and local levels produce large quantities of spatial data, which are often distributed free of cost. The U.S. federal government has been a leader in the production of satellite data, including the Landsat land cover imagery program and the Shuttle Radar Topography Mission (SRTM) elevation product. State and local governments often generate highly accurate data particular to their area. Specifically, parcel or tax assessment data are highly coveted products, almost always produced and maintained by local entities. Due to the indigenous knowledge and proximity of local data producers, attributes, such as addresses, are often created with more care and accuracy than is possible from commercial organizations with a national scope.

Internet trends, exemplified by sites such as Wikipedia, have influenced the data production industry by enabling public communities to easily create and share information. Through services such as Google Earth, individuals can create spatial data by plotting areas and locations on a Web-based interactive map and attributing them with contextual information. Also, many Web sites that facilitate the publishing of personal photographs
on the Internet (e.g., Picasa) include the capability to tag photos with the spatial location at which they were captured. This sector of the data production industry has the potential to proliferate and become a dominant source of spatial data. Consequently, this open style of data production may introduce new and complex issues relating to data integrity, liability, and ownership as it is more widely used.

**Modes of Data Distribution**

Data are a critical component of every geospatial project, and a user’s acquisition of data is therefore a critical consideration. A traditional mode of digital data distribution is via media such as floppy disks, CDs, DVDs, and portable hard drives. Increasingly, however, the quantity of data desired and the speed at which they need to be acquired preclude the use of physical media. In response to this need, entities such as Web-based spatial data clearinghouses make data available via the Internet. For example, Pennsylvania Spatial Data Access (PASDA) provides free access to thousands of spatial data sets either for download or in a number of interactive ways, which are described in later sections of this entry. Other local, state, and federal clearinghouses exist, such as the U.S. federal government’s Geospatial One Stop and National Spatial Data Infrastructure (NSDI) efforts, which aim to facilitate online access to nationwide framework data.

**Geospatial Software Functionality**

**Database Capabilities**

Spatial data storage takes two primary forms: file and database. For raster data, file storage typically takes the form of common image file formats, for example, tiff, jpeg, and MrSID. Vector data consist of a more unique data structure, so more proprietary file data formats are commonly used to handle the spatial geometry component. For example, the Environmental Systems Research Institute (ESRI) supports a vector data format, called the shapefile, that is widely used and is compatible with many software products.

The ability to store spatial data in a commercial database, thereby taking advantage of the benefits of database operations, is a more recent development. Many common commercial database products operate on a relational data model, which is not inherently accommodating of spatial data structures. Database vendors such as IBM and Oracle have produced extensions to their relational database products to accommodate spatial data—DB2 Spatial Extender and Oracle Spatial, respectively. In addition, geospatial software companies produce database add-ons that spatially enable relational databases. For example, ESRI’s Spatial Database Engine (SDE) can be installed into commercial database products such as IBM DB2, Oracle, and Microsoft’s SQL Server to accommodate spatial data.

**Software Capabilities**

The analysis and visualization of geospatial data are most commonly performed in geographic information system (GIS) software. Computer-aided design (CAD) tools perform similar functions and are commonly used in the engineering and drafting industries. Early GIS software products ran on mainframe hardware architectures and presented command line user interfaces. Due to these conditions, early GIS was relegated to expert users. Modern GIS software, however, is developed to run on more accessible operating systems, such as Microsoft Windows, and uses graphical user interfaces (GUIs) in place of the command line. These developments have made modern GIS software accessible to a wide user base of both experts and novices. Furthermore, the production of GIS software has expanded beyond GIS-specific commercial software vendors to untraditional sources. For example, Internet application providers such as Google, MapQuest, and Microsoft have entered the geospatial realm by developing desktop and Internet-based GIS programs that are specifically targeted toward a general, nonexpert audience. These advancements have transitioned GIS from a fringe, specialized technology into a core component of mainstream information technology and society.

**Internet and Mobile Capabilities**

A particularly influential geospatial software development is the use of Web services to deliver geospatial data and functionality over a network.
Web services are a computer programming technique where functionality located at remote locations is consumed over the Internet and used as if stored locally. This technique is commonly used for geocoding, routing, and coordinate conversion. For example, Google Maps offers an application programming interface (API) for embedding an interactive map in any Web site.

Spatial data can be published and consumed over the Internet via map services, which are a type of Web service specific to geospatial data. Map services can be consumed by either a GIS software program or a custom utility, without the need to download and store the actual data locally. Map services make possible the sharing, viewing, and analyzing of large quantities of data, including raster imagery and vector data, seamlessly in a fraction of the time it would take to download the corresponding data files to the local computer. For example, PASDA publishes map services for immediate online viewing or use in a desktop GIS. Other programs, such as Google Earth and NASA World Wind, offer user-friendly interfaces for visualizing and overlaying geospatial data sets, which are stored on remote servers distributed across the Internet.

A burgeoning part of the geospatial software industry involves mobile devices such as personal digital assistants (PDAs), cell phones, and in-car navigation units. These devices use integral GPS receivers and location-based services to provide information relative to their current location. Beyond simply displaying a coordinate location, these GPS-based appliances contain software for displaying other data, such as imagery or roads; performing routing from the current location to many points of interest stored within the receiver’s memory; and using mobile Internet connections to incorporate ancillary information from the Web. Most commercial GPS receiver companies, such as Garmin and Magellan, are producing increasingly sophisticated and compact devices that take advantage of cutting-edge antenna technology and the increasing availability of location-based services.

**Sectors of Software Production**

Private industry remains a dominant producer of geospatial software, including companies such as ESRI, Intergraph, and Autodesk. Commercial products are typically sold at a cost and span the complete range of functionality and platform (i.e., server, desktop, Internet, and mobile). Increasingly, other commercial enterprises that are not traditional geospatial providers are developing products targeted to a more general audience. Google, primarily an Internet search engine, provides basic data visualization tools through a deliberately user-friendly interface in its Google Earth product. Government agencies also provide specialized geospatial software products, such as the U.S. Department of Agriculture’s Fusion program for working with LIDAR (light imaging and ranging) elevation data. Many popular geospatial software applications are produced in an open manner by community-supported efforts, such as the University of Minnesota’s Web-mapping program called Map Server.

In response to a proliferation of geospatial software and data formats, the Open GIS Consortium (OGC) was conceived in an effort to make the diverse geospatial industry more interoperable. In particular, OGC is publishing common communication and format standards for Internet map services, such as the Web Mapping Service (WMS) specification, so that they can be consumed regardless of the client software used.

Ryan E. Baxter

**See also** Applied Geography; Business Geography; Business Models for Geographic Information Systems; Dangermond, Jack; Enterprise GIS; Geodemographics; Geospatial Semantic Web; GIS Software; GIS Web Services; Global Positioning System; Google Earth; Legal Aspects of Geospatial Information; Location-Based Services; Neogeography; Privacy and Security of Geospatial Information; Remote Sensing; Usability of Geospatial Information

**Further Readings**


The term geospatial semantic web has been coined to describe the convergence of three distinct concepts in computing and geographic information science. The first is a geospatial web composed of geospatial information Web services. The second is geospatial semantics—the formal and computable definition of the meanings of geospatial terms. The third concept is the semantic web—representing the growth of the World Wide Web from a web of human-accessible content into a web of data traversed by machine agents.

Almost as soon as the World Wide Web came into being, so too did the idea that content on the Web might have a counterpart in the real world with a corresponding geospatial position, referred to as the spatialization of the Web. Position coordinates alone provided little benefit, though, without capabilities for making maps and forming location-relevant hyperlinks. In the late 1990s, standards organizations such as the Open Geospatial Consortium and vendors such as ESRI and MapQuest began to define, build, and offer geospatial services. Services allowed Web sites to provide dynamically rendered maps of useful information and geospatially relevant links, such as hotels close to a user location, that can be used without much specialized expertise. The usefulness and volume of geospatial data and functionality on the Web has since grown with the deployment of extensive geospatial Web services that allow such resources to be maintained locally and yet accessed globally over the Internet. Even with the development of geospatial catalogs and registries, however, the interconnectedness and hence the value of the resulting “GeoWeb” has been constrained by the difficulty of meaningfully relating data elements from disparate localities and knowledge communities to one another and to Web users at large. The “pushpin on a road map” paradigm has proved a difficult one to move past in terms of large-scale accessibility to geospatial knowledge.

The challenge of making meaningful connections between disparate pieces of information is being addressed by the growing field of formal and machine semantics, using formally defined, logically tractable knowledge representations such as OWL (Ontology Web Language) and explicit expressions of connected data such as RDF (Resource Description Framework). In the geospatial domain, developments such as RCC8 (Regional Connection Calculus) have provided formal definitions of the ways in which the relationships between real-world features can be represented. The goal of geospatial semantics has been to provide standards, representations, and tools that allow localized geographic understanding to be communicated universally.

The remaining challenge to the emergence of the geospatial semantic Web has been to apply geospatial semantic tools and technologies on a Web scale. The means to address this challenge is just beginning to come from geospatial extensions to technologies supporting the development of the semantic Web, including geospatially enabled query languages, spatial inference engines, and geospatial ontologies. Their goal is a Web of geospatial knowledge in which computers create and leverage as well as host connections both between geospatial data elements and with the parts of the physical world they represent.

Joshua Lieberman
Geostatistics has been defined broadly as the study of phenomena that vary over space. Developed originally to address problems of spatial prediction in the mining industry, the generality of the approach has led subsequently to its application in a diverse range of settings across the geographical, geological, atmospheric, environmental, and epidemiological sciences, among others. Geostatistics offers a collection of primarily probabilistic tools that have been developed to aid the understanding and modeling of spatial variability, with the principal motivation of predicting unsampled values dispersed in space (also termed interpolation). The origins of the discipline are generally traced back to the work of Daniel Krige and others on methods for gold and uranium reserve valuation in the Witwatersrand, South Africa, during the 1950s. These ideas were extended and formalized during the 1960s by the French statistician Georges Matheron, who coined the term geostatistics and, with the publication of a series of seminal texts throughout the 1960s and 1970s, laid the foundations for the modern, and still evolving, discipline practiced today by scientists and engineers worldwide.

**Deterministic and Probabilistic Modeling**

The problem motivating the early pioneers of geostatistics, and still the most common goal of contemporary geostatistical analyses, can be stated in the simplest terms as the prediction of a variable (e.g., the concentration of an ore grade) at locations where it has not been sampled (e.g., across a potentially minable deposit). Such predictions require, at least implicitly, the use of a model describing in some way how the phenomenon of interest behaves at these unsampled locations. Various conceptual approaches exist for the formulation of such a model, and a useful categorization is between deterministic and probabilistic models. In a deterministic model, each unknown value is predicted as a single value with no associated prediction error. Such models are best employed when the physical mechanisms that govern the variable of interest are well understood and established physical equations exist that allow calculation of the unknown value with negligible or no error. In fields such as environmental, epidemiological, and public health sciences, however, the systems of interest are often of such complexity and scale that they retain an inherent unpredictability, even when many of the constituent processes are understood in detail, meaning that a deterministic model may be neither feasible nor appropriate. Probabilistic models represent an alternative paradigm to deterministic approaches by considering the underlying mechanism that generates observed data and, by extension, that determines values at unsampled locations, as a random process. Although the mechanism in question is rarely, if ever, entirely random, the adoption of a probabilistic model provides a framework that can prove extremely useful in both predicting unsampled values and assessing the uncertainty of those predictions. Instead of predicting a single value for each unsampled location with assumed zero error, probabilistic models allow the prediction of a set of possible values with corresponding probabilities of occurrence. Unlike deterministic models, probabilistic models do not necessarily require knowledge of the physical process that generated sample data. Rather, most of the information used is derived from the data.

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The Random Field Model

While geostatistics is today a broad and multifaceted statistical toolbox, a core conceptual component—the random field model—underpins its many constituent techniques. A spatial random field (also known as a random function) is defined as a set of usually dependent random variables \( F(x) \), one for each location \( x \) in a study area of interest. Just as a univariate probability distribution can be used to represent uncertainty around the unknown outcome value of a random variable, a multipoint probability distribution can be used to represent the joint uncertainty around outcome values at any given set of \( n \) locations spatially distributed across a study area. Treating spatial data as observations from a random field, and using those observations to characterize the field’s properties, provides a framework for estimating values at unobserved locations. Strictly, a random field is only characterized fully by what is known as its complete spatial law: the theoretical set of multipoint probability distributions for every possible set of locations across the field. In practice, such complete characterization is both infeasible and unnecessary for the prediction of unsampled values. As a practical alternative, the much simpler joint relationship between random variables at just two locations at a time, say \( F(x) \) and \( F(x + h) \), can be characterized by the one- and two-point probability distributions. The symbol \( h \) in this context refers to lag, the separation distance (and direction) between the two locations in question. Under conditions of stationarity (discussed in more detail below), the degree of dependence between two random variables separated by the same lag is the same for any such pair \( F(x) \) and \( F(x + h) \) across the study area. Under these conditions, a number of parameters of the random field exist that summarize this bivariate dependence, including the covariance function and the semivariogram. The latter can be expressed as

\[
\gamma(h) = 0.5(E[(F(x) - F(x + h))^2]),
\]

which defines semivariance \( \gamma \) between two random variables separated by a lag \( h \) as half their expected squared difference. The adoption of a random field model and its parameterization via the semivariogram provides a powerful framework for the prediction of unsampled values dispersed in space. The following section describes the principal considerations and tools by which this framework is implemented.

Spatial Prediction With Geostatistics

Stationarity

Strict stationarity entails that the multivariate probability distribution for random variables at any arbitrary set of locations across the field is spatially invariant, such that the set of locations could be translated to anywhere else on the field without modifying the probability distribution, that is, the statistical properties of the field are the same throughout. A less stringent definition of stationarity, known as second-order stationarity, has two requirements: (1) that the underlying expectation (the theoretical mean value) of the field is invariant with location and (2) that any pair of random variables separated by the same lag \( h \) share the same two-point probability distribution, regardless of the absolute location of the pair. In a further weakened definition known as intrinsic stationarity, this latter requirement is relaxed so that it is sufficient that the increments of the random field, that is, the differences between values in a pair separated by a given lag, are second-order stationary. One reason for the centrality of the variogram for characterizing the random field in geostatistics is that, unlike the covariance function, its existence and inference require only intrinsic stationarity, a modeling assumption that can be justified in a wider range of settings than the more rigorous definitions of strict or second-order stationarity.

Variography: Inferring the Structural Properties of a Random Field

There are two related motivations for aiming to characterize a random field by estimating its variogram from observed data. First, semivariance can be thought of as a measure of dissimilarity between values of the random field as a function of their separation distance and direction. By describing semivariance across a range of possible lags, the semivariogram acts as a useful
exploratory and descriptive tool, providing a summary of the second-order properties (i.e., the spatial autocorrelation structure, or texture) of the phenomenon under study that may provide insight into the underlying physical or biological processes. Second, prediction algorithms such as kriging, described in more depth below, require that the dependence between random variable pairs at different lags be characterized. In both cases, the semivariogram must be estimated from a sample of data obtained at locations dispersed across the area of interest. The most common approach taken is to estimate the semivariogram from $n$ sample data using a straightforward method-of-moments approach. For each lag $h$, the sample semivariogram $\hat{\gamma}(h)$ can be estimated as half the mean squared difference between all $i = 1, 2, \ldots, l$ data pairs separated by that lag:

$$\hat{\gamma}(h) = \frac{1}{2l(h)} \sum_{i=1}^{l(h)} [f(x_i) - f(x_i + h)]^2.$$

Semivariance values can be calculated for every data pair in the data set and compared with the corresponding lags by plotting the resulting variogram cloud. An alternative approach is to pool data pairs according to a finite set of regularly spaced lags, with each value of $h$ actually representing a defined range of lag separations. The latter approach allows a larger sample, and hence a more stable estimate, for each estimated value of $\hat{\gamma}(h)$. A further issue is the effect of direction on the variogram. Where semivariance is dependent only on the separation distance, the variogram is deemed isotropic. Where the direction of separation also has an effect, the variogram is deemed anisotropic. In the latter case, data pairs are generally pooled by both distance and direction, and separate sample variograms are estimated for each direction. Interpolation algorithms such as kriging require semivariance values for any possible lag. As such, it is necessary for these purposes to fit a continuous model $\hat{\gamma}(h)$ to the sample semivariogram.

**Simple Kriging**

The term kriging was introduced by Georges Matheron (in recognition of the earlier work of Daniel Krige) to describe a family of generalized linear regression techniques that provides an approach by which a set of spatial data $f(x_j)$, collected at spatially dispersed locations across a study area, can be used to predict the values, $f'(x_j)$, at a set of unsampled locations (where the asterisk denotes a predicted value). Kriging techniques operate within the conceptual framework provided by the random field model and exploit spatial autocorrelation (also termed spatial dependence) in the phenomenon of interest, as modeled by the covariance function or semivariogram. The theoretical difference (or error) between the predictions and the unknown true values at those locations is defined as $F(x) - F'(x)$. Kriging is known as a best linear unbiased predictor, which implies two properties with regard to this error: (1) that the expectation of the error is zero (i.e., the predictor is unbiased) and (2) that the expected variance of the error, $\sigma^2(x)$ (also termed the kriging variance), is minimized (i.e., the predictor does the “best” job possible by minimizing the expected magnitude of prediction errors given the available data and the parameterization of the random field). Numerous variations of kriging exist, each targeted at subtly different prediction problems. In simple kriging, the random field $F(x)$ is considered to consist of a trend component with a known mean $m(x)$ and a residual component $R(x)$. The simple kriging estimator $F_{sk}(x)$ can be defined as

$$F_{sk}(x) = \sum_{d=1}^{n(x)} \lambda_d(x)F(x_d) + \left[1 - \sum_{d=1}^{n(x)} \lambda_d(x)\right]m,$$

where $\lambda_d$ are termed the kriging weights and determine the influence of each observed datum on the predicted value. A minimization procedure can be implemented to derive the set of kriging weights in order to minimize the error variance, $\sigma^2(x)$. In matrix notation, this procedure can be summarized as

$$C_{dd} \cdot \lambda_{sk} = C_{dp},$$

where $C_{dd}$ is an $n \times n$ matrix of the covariances between random variables at the data locations, $C_{dp}$ is a vector of the $n$ covariances between random variables at data locations and the prediction location, and $\lambda_{sk}$ is a vector of the $n$ kriging...
weights. Covariance values to populate these matrices can be derived, using the assumption of stationarity, from the model fitted to the sample semivariogram. The vector of kriging weights is obtained by the matrix product of the inverted data-to-data covariance matrix $C_{dd}^{-1}$ and the data-to-prediction covariance vector, $C_{dp}$:

$$
\lambda_{sk} = C_{dd}^{-1} \cdot C_{dp}.
$$

Multiplying this vector of weights with the corresponding vector of data values $f(x_d)$ and summing across the resulting vector provides the final simple kriging prediction.

**The Kriging Variance**

The attractive qualities of kriging as an interpolation technique lie in its minimization of the error variance under the constraint of unbiasedness. As well as being a critical intermediate stage of the kriging computation, the calculation of this error, or kriging variance, is extremely useful in its own right because it acts as an objective measure of the uncertainty associated with each prediction. The simple kriging variance, calculated using the same covariance matrices described above, is defined as

$$
\sigma_{sk}^2(x) = C(0) - C_{dp}^T \cdot C_{dd}^{-1} \cdot C_{dp},
$$

where $C(0)$ denotes the covariance at lag zero. The kriging variance is dependent on the variogram or covariance model and on the spatial configuration of the data in relation to the prediction location. Because of this dependence, the kriging variance provides a measure of the uncertainty of each prediction, with uncertainty increasing for random fields with large spatial variability and for predictions that are made at locations more distant from data. Kriging variance is not dependent, however, on the data values, such that any two sets of data with different values but the same spatial configuration would yield a prediction with the same kriging variance. This independence reduces the utility of the kriging variance as an absolute measure of uncertainty since, for example, it is intuitive that a local set of data with large variability will result in a less certain estimate than a less variable set with the same spatial configuration. As such, the use of kriging variance is generally restricted to a relative measure of uncertainty, allowing relative comparison of the uncertainty of individual predictions and different data configurations. The kriging variance is often used in this context for the design and evaluation of different sampling schemes prior to data collection. Because the kriging variance is independent of the actual observed values, different schemes can be assessed on paper before any data are collected. Assuming that a reasonable model for the variogram can be inferred, either from a small pilot survey or from existing knowledge, then the relative efficiency and cost of candidate sampling schemes can be evaluated and potentially optimized using the kriging variance as a measure of the predictive accuracy that can be expected at each location to be predicted.

**Other Common Kriging Algorithms**

A second and perhaps more widely used member of the kriging family of algorithms, known as **ordinary kriging**, differs conceptually from simple kriging in the way the trend component of the random field $m(x)$ is modeled. Rather than considering this component as known, ordinary kriging considers the mean to be unknown and limits its domain of stationarity to a local neighborhood centered on the location $x$ to be predicted. This approach has the important practical implication that the local mean may vary considerably over the study area, which, in practice, is often considered a more appropriate modeling strategy. The rationale of incorporating a varying mean is extended by **kriging with a trend model**, sometimes called **universal kriging**, in which the trend component $m(x)$ is modeled by the automatic estimation within each local neighborhood of a simple linear or low-order polynomial function. In many settings, the target variable to be predicted is related, at least empirically, to one or more secondary variables that coexist within the study area of interest, implying that the variation in the primary variable may be partially explained by the variation in these covariates. If covariate data are available, it may be helpful to incorporate them in the prediction of the primary variable. If such data are available at both the data locations and all locations to be predicted, a technique called **kriging with an external drift** can be used. This can be
considered a straightforward extension to kriging with a trend model, in which the local trend components are defined not as linear functions of location but as functions of the covariate data. Cokriging acknowledges the separate spatial structures of the primary and any secondary variables, as well as their cross-correlations, to provide an elegant method for incorporating covariate data not necessarily collocated with the available data or available at all prediction locations.

Quantifying Prediction Uncertainty

A key limitation of kriging for certain applications is that while the kriging variance provides a useful measure of relative prediction accuracy, it cannot in general be treated as an absolute measure, as required, for example, in the definition of confidence intervals around predictions. A family of geostatistical algorithms has been developed to address this limitation. In multi-Gaussian kriging, observed data are subjected to a normal-scores transform before the standard procedure of variogram estimation and modeling, and prediction via simple kriging. Because the transformed random field can, subject to a number of assumptions, be considered multivariate Gaussian, the value of the field at each prediction location can be considered to have a univariate Gaussian distribution fully specified by the kriging prediction (which parameterizes the mean of the distribution) and kriging variance (parameterizing the variance of the distribution). Values can be simulated from each of these predictive distributions and subjected to a back-transform to provide, for each prediction location, a set of realizations that together constitute a model of the posterior predictive distribution from which summary point estimates and confidence intervals can be calculated. The sequential Gaussian simulation algorithm extends this procedure to allow joint realizations of all prediction locations simultaneously rather than independently. The resulting set of back-transformed realizations provides a model of uncertainty that can be averaged or summed spatially to obtain posterior predictive distributions of regionally aggregated quantities. Indicator kriging and the sequential indicator simulation algorithms provide parallel nonparametric approaches.

Peter Gething

See also Analytical Operations in GIS; Bayesian Statistics in Spatial Analysis; Geocomputation; Geographically Weighted Regression; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Interpolation; Spatial Statistics

Further Readings


Geothermal Energy

Geothermal energy is the heat contained within Earth that generates geological phenomena on a planetary scale. The term geothermal energy is often used to indicate that part of Earth’s heat that can, or could, be recovered and exploited by humans. The presence of volcanoes, hot springs, and other thermal phenomena clearly demonstrates that the interior of Earth is hot: Earth’s temperature increases with depth.
This heat is continually generated by the decay of the long-lived radioactive isotopes of uranium ($^{238}\text{U}$, $^{235}\text{U}$), thorium ($^{232}\text{Th}$), and potassium ($^{40}\text{K}$), which are present in Earth, in addition to the primordial energy of planetary accretion. The total heat content of the crust of Earth can be estimated in the order of $5.4 \times 10^{21}$ MJ (megajoules). As a comparison, the total world electricity need per year is about $6 \times 10^{13}$ MJ, that is, 100 million times lower. The thermal energy of Earth is therefore immense, but only a modest fraction can be used by people. Human use is limited to areas in which geological conditions permit a carrier (water in the liquid phase or steam) to “transfer” the heat from deep hot zones to or near the surface, thus giving rise to the geothermal resource.

A geothermal system can be described schematically as convecting water in the upper crust of Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface. A geothermal system is made up of three main elements: a heat source, a reservoir, and a fluid, which is the carrier that transfers the heat (Figure 1). The heat source can be either a very high-temperature ($>600 \, ^\circ\text{C}$) magmatic intrusion that has reached relatively shallow depths (5–10 km [kilometers]) or, as in certain low-temperature systems, Earth’s normal temperature. The reservoir is a volume of hot, permeable rocks from which the circulating water is generally overlain by a cover of impermeable rocks and connected

**Figure 1**  Schematic representation of a typical geothermal system

to a superficial recharge area through which the meteoric waters can replace or partly replace the fluids that escape from the reservoir.

**Geothermal History**

In the early part of the 19th century, geothermal fluids were already being exploited for their energy content. A chemical industry was set up in that period in Italy, in the zone now known as Larderello, to extract boric acid from the hot waters issuing naturally or from specially drilled shallow boreholes. In 1827, Francesco de Larderel developed a system for using the heat of the geothermal fluids in the evaporation process, rather than burning wood from the rapidly depleting forests. Between 1910 and 1940, the low-pressure steam in this area of Tuscany was brought into use to heat the industrial and residential buildings and greenhouses. In 1928, Iceland, another pioneer in the use of geothermal energy, also began exploiting its geothermal fluids for domestic heating.

The first attempt at generating electricity from geothermal steam was made at Larderello in 1904. The success of this experiment indicated the industrial value of geothermal energy. By 1942, the installed capacity had reached 128 MWe (megawatts electrical). The example set by Italy was followed by several countries. The first geothermal wells in Japan were drilled at Beppu in 1919 and in the United States at The Geysers, California, in 1921. In 1958, a small geothermal power plant began operating in New Zealand, in 1959 in Mexico, in 1960 in the United States, and in many other countries in the years to follow.

**Present Use of Geothermal Energy**

After World War II, many countries were attracted by geothermal energy, considering its economical value: It did not have to be imported, it was available 24 hours per day, it was independent of external weather conditions, and, in many cases, it was the only energy source available locally for the benefit of local populations. Geothermal resources

![Figure 2](image-url)  
*Figure 2* Installed capacity (left) and energy production (right) for geothermal electricity generation and direct use (heating) in the different continents. The Americas include North, Central, and South America.

have been identified in 90 countries, and there are quantified records of geothermal use in 72 countries. Summarized information on geothermal use in the individual countries for electricity production and direct use (heating) is available. In 2004, the worldwide use of geothermal energy was about 57 TWh/yr. (terawatt hours per year) of electricity and 76 TWh/yr. for direct use. The installed electric capacity in 2004 was 8,900 MWe. The installed capacity for direct applications in 2004 was 28,300 MWth (megawatts thermal). Figure 2 shows the installed capacity and the geothermal energy in the different continents in 2004. Figure 3 shows the short-term forecasting of the installed capacity for electricity production in 2010 in different countries.

Figure 3  Forecast of the installed capacity for electricity production in 2010 in different countries


Geothermal Potential

Geothermal energy sources have been considered exploitable, until recently, only in areas where the fluid is found at depths less than 4 km with temperatures above 180 °C. This has changed in the past two decades with the development of power plants that can economically use lower temperature resources (down to 100 °C) and the emergence of ground source heat pumps using Earth as a heat source for heating or as a heat sink for cooling, depending on the season. This has made it possible to use the heat of Earth for heating and/or cooling, as appropriate.

It is difficult to estimate the overall worldwide potential because of large uncertainties.
Nevertheless, it is possible to identify a range of estimations, taking also into consideration the possibility of new technologies, such as permeability enhancements, drilling improvements, enhanced geothermal systems (EGS) technology, low-temperature electricity production, and the use of supercritical fluids. One estimate of the expected geothermal electricity potential is 35–70 GW (gigawatts) to 140 GW (Figure 4).

It is considered possible to produce up to 8.3% of the total world’s requirement of electricity with geothermal resources, serving 17% of the world population. Thirty-nine countries (located mostly in Africa, Central/South America, and the Pacific) can potentially obtain 100% of their electricity from geothermal resources.

**Geothermal Field Classification**

Frequently, a distinction is made between water- or liquid-dominated geothermal systems (also called hydrothermal energy) and vapor-dominated or dry steam geothermal systems (including hot, dry rocks). In water-dominated systems, liquid water is the continuous, pressure-controlling fluid phase. These geothermal systems, whose temperatures may range from 100 to 225 °C, are the most widely distributed in the world. In vapor-dominated systems, liquid water and vapor normally coexist in the reservoir, with vapor as the continuous, pressure-controlling phase. Geothermal systems of this type, the best known of which are Larderello in Italy and The Geysers in California, are somewhat rare and are high-temperature systems (>300 °C).

**Direct Use of Geothermal Heat**

Electricity generation is the most important form of use of high-temperature geothermal resources (>150 °C). The medium-to-low temperature resources (<150 °C) are suited to many different types of application.

Space and district heating systems have made great progress in Iceland, where the total capacity of the operating geothermal district heating system had risen to about 1,200 MWth, but they are also widely distributed in the East European countries as well as in the United States, China, Japan, France, and so on.

*Space cooling* is a feasible option where absorption machines can be adapted to geothermal use. The technology of these machines is well-known, and they are readily available on the market. The absorption cycle is a process that uses heat instead of electricity as the energy source. The refrigeration effect is obtained by using two fluids: (1) a refrigerant, which circulates, evaporates, and condenses, and (2) a secondary fluid or absorbent.

The agricultural applications of geothermal fluids consist of open-field agriculture and greenhouse heating. Thermal water can be used in open-field agriculture to irrigate and heat the soil. The most common application of geothermal energy in agriculture is, however, in *greenhouse heating*, which has been developed on a large scale in many countries. Greenhouse heating can be accomplished by forced circulation of air in heat exchangers, hot water-circulating pipes or ducts located in or on the floor, or other methods. Exploitation of geothermal heat in greenhouse heating can considerably reduce operating costs, which in some cases account for 35% of the product costs.

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Figure 4  Estimated world geothermal electricity potential

Aquaculture, which is the controlled breeding of aquatic forms of life, is gaining worldwide importance nowadays. By maintaining an optimum temperature artificially, we can breed more exotic species, improve production, and even, in some cases, double the reproductive cycle.

**Conclusion**

Geothermal energy is a renewable energy source that has been used economically in many parts of the world for decades. The geothermal exploitation is renewable because of the total reinjection of the cold water after its use, so that only the heat is mined out of the rocks, but it is continuously recharged (directly or indirectly) by Earth’s heat flux. A great potential for an extensive increase in worldwide geothermal use has been proven. This is a reliable energy source that serves both direct-use applications and electricity generation. Geothermal energy is independent of weather conditions and has an inherent storage capability, which makes it especially suitable for supplying base load power in an economical way, and can thus be used along with energy sources that are only available intermittently. The renewable energy sources can contribute significantly to the mitigation of climate change and more so if they are used in combination, rather than in competition, with each other.

Geothermal exploitation techniques are being rapidly developed, and knowledge of the reservoirs has improved considerably over the past years. Combined heat and power plants are gaining popularity, improving the overall efficiency of geothermal use. Also, low-temperature power generation with binary plants has opened up the possibility of producing electricity in countries that do not have high-temperature fields. EGS technologies, where heat is extracted from deeper parts of the reservoir than in conventional systems, are under development. If EGS can be proven economical at commercial scales, the development potential of geothermal energy will be limitless in many countries of the world.

Ruggero Bertani

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**Further Readings**


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**Geothermal Features**

Geothermal features are surface manifestations of the internal heat of Earth interacting with groundwater. Earth’s internal heat developed during the early evolution of the planet, and additional heat is generated by the decay of radioactive elements, primarily uranium, thorium, and potassium. However, the most important heat source is shallow magma bodies and associated volcanic activity.

Geothermal areas can be classified into high temperature and low temperature, based either directly on subsurface water temperatures or indirectly on the geological settings. High-temperature geothermal areas have water temperatures in the uppermost 1,000 m (meters) of greater than 200 °C. Low-temperature geothermal areas are characterized by water temperatures ranging from close to 20 to 150 °C and can be found in formerly active volcanic regions, on the margins of
active volcanic regions, or in areas where there is a deep component of groundwater flow, combined with geological features, such as faults or fracturing, that allow the upward movement of heated water to the surface. The primary water source for most geothermal regions is meteoric water, usually as recharge to an aquifer.

High-temperature geothermal areas form where there is a high-temperature gradient due to the presence of a shallow magma body (typically at around 15–5 km [kilometers], i.e., 9–3 mi. [miles] depth). Because groundwater at depth is subjected to greater pressures than shallow groundwater, it can remain in a liquid state while reaching temperatures greater than 100 °C. Consequently, in high-temperature geothermal areas, groundwater typically reaches temperatures of around boiling point at 1 km (0.6 mi.) depth, and it can reach temperatures of more than 350 °C at 3 km (2 mi.) depth. Groundwater that is heated at depth becomes less dense and rises to the surface. If the temperature exceeds the boiling point as it reaches the surface, then it is emitted as steam. Most high-temperature geothermal fields are associated with young and active rhyolitic volcanism. A faulted, fractured, or porous host rock is necessary to allow water to move from the heat source to the surface. Depending on the temperature at which the water emerges, and the surface conditions, it can form a range of geothermal features, including fumaroles, mud pots, hot springs, and geysers.

**Fumaroles**

A fumarole is any vent in Earth’s surface from which steam is emitted. Fumaroles form in geological settings where groundwater is maintained at temperatures in excess of the boiling point close to the surface. Steam temperatures can range from 98 °C to as high as 1,000 °C, but commonly in the range of 200 to 300 °C. As such, fumaroles are always found in association with active volcanism or in high-temperature geothermal fields associated with very shallow magma chambers. Where there is no well-defined vent, a steam field may develop, where steam is emitted from porous ground over a wide area.

The steam from fumaroles is generally composed of a range of gases in addition to water vapor. Typically, these include carbon dioxide (CO₂), sulfur dioxide, hydrochloric acid, and hydrogen sulfide. The ratio of water vapor to gas varies depending on the temperature of the steam, rising to more than 20% at temperatures of approximately 300 °C but falling again at higher temperatures (>500 °C). Fumaroles that emit sulfurous gases are sometimes referred to by the term solfatara, particularly in Italy. Hydrogen sulfide present in the steam (which produces the distinctive “rotten egg” smell common in geothermal areas) tends to be oxidized at the surface by atmospheric oxygen, either into elemental sulfur,
which is deposited around the vents, or into sulfuric acid. For this reason, surface water around steam vents can be highly acidic, with pH values as low as 1. This acidic surface water reacts easily with volcanic material to form fine-grained silica and clay mixtures.

**Mud Pots/Mud Pools**

*Mud pots* and *mud pools* are often found in close association with fumaroles, as they form in areas of relatively limited water supply but with abundant steam being vented. As described above, hydrogen sulfide in venting steam reacts with atmospheric oxygen to form sulfuric acid, which breaks down surface material into a fine clay. Mixed with the water from low-discharge hot springs, and venting steam, this fine-grained mixture produces the effect of a boiling mud pot in which bubbles of mud slowly grow and then “pop.” Usually, the mud is a dark gray color, but depending on the chemical composition of the source rocks, it can be brightly colored and is sometimes referred to as a *paint pot*.

**Hot Springs**

*Hot springs* form where geothermally heated water emerges from Earth. Depending on the geological setting, the temperatures in a hot spring can range from just above ambient to nearly boiling. There is no widely accepted definition of exactly what a hot spring is. The most commonly accepted definition is that a hot spring is any spring where the water temperature is above the ambient temperature, where *ambient* is loosely defined as the “temperature of the surroundings.” Another common definition is water temperature above 36.7 °C (the human body temperature), although this is often considered to be too anthropocentric.

Hot springs can be found on all continents and in both terrestrial and marine settings. Low-temperature geothermal springs usually have deep water sources and are connected to the surface by faults or fractures. Geothermal water typically has a high dissolved mineral load. The exact composition of geothermally heated water depends on the host geology. Low-temperature geothermal systems are usually dominated by carbonates, while high-temperature geothermal systems are usually enriched in silicic minerals due to their close association with volcanic rocks, especially rhyolite. As mineral-rich water overflows the edge of a hot spring, or flows over the adjacent ground, it precipitates its dissolved load, leading to the deposition of distinctive deposits called *sinters*. Sinters formed from carbonate minerals are called *travertines*, while those formed from silicic minerals are referred to as *siliceous sinters*. Extensive silica terraces are a common feature of many geothermal areas. The warm and mineral-rich conditions in hot spring sinter deposits encourage colonization by a variety of microbial organisms, primarily cyanobacteria. The uptake of CO₂ by bacterial photosynthesis may encourage rates of sinter precipitation, although generally, the loss of CO₂ to the atmosphere is the primary mechanism of precipitation. Bacteria may also play a role in controlling the internal structure of some sinter deposits.

**Geysers**

*Geysers* are hot springs that periodically “erupt,” forcing water into the air. Geysers are relatively rare, with only around 1,000 of them occurring globally. This is because in addition to the heat source and water supply necessary for other geothermal features, they also require a distinctive reservoir and plumbing system. Almost all geysers occur in areas of rhyolitic volcanic rock, although a small number are hosted in other igneous rocks. Rhyolites are especially common because their high silica content encourages the deposition of siliceous sinters on the inside of their vents, creating a watertight plumbing system that allows high pressures to be reached. The structure of a geyser consists of a standpipe, which terminates at the surface in a cone or shallow pool, and one or more reservoirs. The water in a geyser plumbing system consists of deep-circulating high-temperature geothermal water entering the system from below and cooler surface water entering from above. Where the two water sources meet, the hotter, less dense water will begin to condense and gradually heat the cooler water until it also reaches boiling point. At this point, steam bubbles from the hotter water will begin to move upward through the cooler water. In geysers with a constrictive
opening, the pressure of the rising steam will build up behind the constriction, eventually lifting the overlying water to allow the steam to escape, thus lowering the pressure, allowing the already boiling water to boil even more vigorously, and turning more water to steam as it does so. This process causes a rapid expansion of steam and water that ejects violently through the constriction. The explosion continues until there is no more water in the reservoir or the water temperature drops below boiling. Depending on the size of the geyser and the available heat source, this cycle of filling, heating, and erupting can take from minutes to days.

### Geographical Distribution of Geothermal Features

The distribution of geothermal features is strongly controlled by the distribution of available heat sources and is consequently closely related to the distribution of volcanic activity across the globe. The distribution of volcanoes is primarily determined by the distribution of Earth’s tectonic plates, and many geothermal areas occur in association with the volcanism that occurs along plate boundaries. High-temperature geothermal areas occur at divergent plate boundaries (mid-oceanic ridges and rift valleys) and convergent boundaries (along cordilleras, volcanic arcs, and back-arc basins). Continent-to-continent collision zones usually develop only low-temperature geothermal areas. Most of the major geothermal areas on the Pacific Ring of Fire are associated with convergent boundary subduction zones. Other geothermal areas occur in conjunction with volcanic hot spots (volcanic areas formed by mantle plumes), primarily in locations away from plate boundaries, such as the Yellowstone geothermal area or the Hawaiian volcanic islands. Iceland is located on a divergent plate boundary (a midoceanic ridge) that is coincident with a hot spot. As volcanic areas become dormant or extinct or a tectonic plate moves over a hot spot, changing the center of volcanic activity, a geothermal area can change in character from high temperature to low temperature.

The most famous geothermal area is Yellowstone National Park in the United States. Yellowstone contains a total of 10,000 geothermal features distributed across seven geothermal basins within the region, including approximately 500 geysers (around one half the world’s total) and 4,000 fumaroles. Other geothermal areas in the Western United States include the Beowawe Geyser Field, Nevada, and Steamboat Springs, Colorado, but the geyser activity at these sites has been damaged by geothermal power exploitation. A small geothermal area with geysers exists on Unmnak Island, an Aleutian Island close to the Alaskan mainland.

Iceland is famous for the geyser “Geysir,” from which all other geysers are named. The name geysir is derived from the Icelandic verb gjósa (meaning “to erupt”). Geysir is the world’s oldest recorded geyser, with accounts dating back to 1294. During the 19th and 20th centuries, Geysir was relatively inactive. Geysir has been reactivated by major earthquakes (most recently in 2000) and during the 1980s by pouring soap into the vent, a practice that has since been discontinued due to environmental concerns.

All of New Zealand’s active high-temperature geothermal fields are on the North Island. The Taupō volcanic zone lies in the center of the North Island and extends from the southwest to the northeast for 350 km (217 mi.). There are more than 100 low-temperature geothermal areas across both North and South Islands, associated with older volcanic regions. In the 19th century, there were five major geyser fields within the Taupō volcanic zone: Rotomahana, Whakarewarewa, Örakei Kōrako, Wairākei, and Taupō Spa. The Rotomahana geyser field was destroyed by the 1886 eruption of Mt. Tarawera, and most of the remaining geyser fields have been damaged by geothermal power development, such that the number of recorded geysers in New Zealand had decreased from 220 in the 19th century to 58 in 2004. Whakarewarewa is the largest of the active geothermal areas, with some 500 hot springs and 65 geyser vents, 7 of which are active.

Other geothermal areas include the Valley of Geyser in the Kamchatka Peninsula, Siberia, and El Tatio in the Chilean Andes.

Philip M. Marren

See also Earthquakes; Geothermal Energy; Groundwater; Plate Tectonics; Volcanoes
Further Readings


GETIS, ARTHUR (1934–)

Arthur Getis is Distinguished Professor of Geography, Emeritus, at San Diego State University. He received his BS and MS degrees at the Pennsylvania State University and completed his PhD in geography at the University of Washington in 1961. Getis was a student of William Garrison and, together with his fellow graduate students, took part in the “quantitative revolution” in geography. He is widely known across disciplines for his research in spatial statistics and has made significant contributions in all aspects of academic geography.

Getis’s early work analyzed the patterns of economic activity using map transformations and pattern analysis techniques borrowed from ecology. His manuscript titled “Temporal Land Use Pattern Analysis With the Use of Nearest Neighbor and Quadrat Methods” appeared as the first discussion paper in the Michigan Inter-University Community of Mathematical Geographers (MICMOG) series in 1963. The paper reached a wider geography audience a year later, when it was reprinted in the Annals of the Association of American Geographers. He has since published scores of scholarly articles in the top journals of the field. Two books, coauthored with Barry Boots, examine the connections between process and spatial pattern and demonstrate pattern analysis techniques.

Much of Getis’s recent work has focused on the development of methods for spatial analysis and spatial econometrics. He has been influential in advancing local methods of spatial analysis, and his most often cited research is the development of local spatial clustering statistics with J. Keith Ord. He has also employed local spatial statistics to account for and incorporate spatial dependence in regression analysis. The subject matter of his work has shifted to understanding and improving the health of populations. He is currently conducting research on dengue fever transmission, fertility, and women’s health in developing regions.

Getis has received several awards honoring his scholarship, including the Walter Isard Award from the North American Regional Science Association and Distinguished Scholarship Honors from the Association of American Geographers. He held the Stephen and Mary Birch Foundation Endowed Chair of Geographical Studies at San Diego State University from 1992 to 2004.

Getis has worked to advance geographic education at all levels. He has written several popular textbooks, including Introduction to Geography, coauthored with Judith Getis and Jerome Fellmann, which is now in its 12th edition. He has taught at a number of prestigious universities and in several interdisciplinary workshops. His graduate advisees include Barry Boots of Wilfrid Laurier University, Kingsley Haynes of George Mason University, and Marc Armstrong of the University of Iowa.

Getis also has an extensive record of service at departments, universities, and professional organizations. Past leadership roles include head of the department of geography and director of the School of Social Sciences at the University of Illinois. He has served as president of both the Western Regional Science Association and the University Consortium for Geographical Information Sciences. He is a founding editor of the Journal of Geographical Systems, together with Manfred Fischer.

Jared Aldstadt
The concept *ghetto* is much debated and controversial in Anglophone geography, the social sciences, and public policy. Conflicting and clashing ideologies—conservatism, liberalism, and radicalism—all proclaim a definitive unearthing of its essence. Many agree that the concept today references a distinctive space inhabited by one stratum of the American population: the poor and relatively isolated. This space, almost universally associated with U.S. cities, identifies a core of underemployed and unemployed persons whose limited social and spatial mobility confines them to the inner city. In this context, a population disproportionately black and Latino is distinguished on the basis of material deprivation, lack of opportunities for upward mobility, limited spatial mobility, and immersion in disinvested neighborhoods. The pathbreaking exposition of black ghettos in urban America by Harold Rose in 1971 was pivotal to centering this notion within contemporary Anglophone human geography.

Yet there is much disagreement about the ghetto’s specifics, that is, the causes for its existence and perpetuation and for its precise social attributes. Neoconservatives posit a space-trapped population who fall prey to their own production of a pernicious, ensnaring “ghetto subculture.” Poor people, in often dire realities, reflexively and consciously opt for a lifestyle of limited responsibility, peripheral commitment to wage labor, and adherence to short-term, hedonistic pursuits, as place-specific, “ghetto” values are mediated and acted on. Ghettos here evolve as increasingly separate, distinctive social worlds whose unique values seamlessly circulate in life’s everyday circuitries to produce a problematic type of being: “ghetto people.”

Alternatively, liberal and radical perspectives chronicle a contemporary ghetto with different social attributes. Both are remarkably similar in identifying a resource-deprived space that embeds a population and institutional fabric bearing hopelessness, the struggle to achieve against great obstacles, and discord in the face of class and racial oppression. A reality comprising barriers, racism, discrimination, and lack of access to resources and facilities is seen to be ceaselessly mediated by and shaping a population’s everyday life and sense of future material prospects. Ghettos, then, are seen to house a population struggling to be the same rather than choosing change, opting for an alternative demographic. What ghetto residents most desire—decent material foundations, steady jobs, meaningful lives, resource-rich communities—is identical to the desire of every other population group but is extremely difficult to obtain in these isolated, deprived, and stigmatized spaces. Where there is deviance and deformity, it is suggested, there is the debilitating impact of hopelessness spawned by racism, grinding poverty, and the everyday struggle to survive.

At the same time, much disagreement exists about the reasons for this space’s continued existence. Neoconservatives emphasize the driving power of a humanly created subculture: “the subculture of poverty.” This perspective emphasizes the interconnection between human choice, created cultural traditions, and individual character, which places cause in the realm of human actions and choices. Here, the creation and sustaining of ghettos is a culturally driven affair. Faced with difficult everyday realities, people create their own social worlds via conscious decision making to adapt to marginal circumstances. The
construction of different norms allows people to attain goals, ones that are frequently impugned by the larger society. Amid pervasive feelings of resignation, passivity, fatalism, and powerlessness, the failure to self-discipline, an unwillingness to defer gratification, and the marginalization of the work ethic propel the formation of a distinctive population and space. In the end, people have difficulty holding jobs, fail to see the utility of working hard, and become transient economic actors who perpetuate poverty, reduce life chances, and sustain the economic and social environment of a ghetto.

Liberal and radical visions dispute this explanation. The liberal stance posits that everyday realities are a product of human choices but within a powerful causal force: bounded and constrained circumstances. Human choice, then, is anything but “pure” and unfettered. In this context, poverty and deprivation are complex end products of people having to routinely negotiate a litany of structural forces—for example, low-income–punishing labor markets, a distant and hostile government, identity-punishing everyday realities, and degrading social welfare programs. At issue are the powerful realities of a postindustrial economy with declined numbers of decent-paying jobs, aloof public bureaucracies, and minority and low-income hostilities embedded in the common institutional actions and common affairs that sear everyday ghetto life.

The radical vision more deeply contextualizes the realities of these spaces by situating them within the totality of capitalist social and economic organization. Its starting point is the notion that inequality is inherent in the capitalist mode of production. Inequality is inevitably produced in the normal operation of capitalist economies and social processes and cannot be eradicated without fundamentally altering the mechanisms of capitalism. Thus, capitalist economies need pools of low-wage workers as both regular and sporadic participants, the latter being deployed periodically to drive wage rates down. In this setting, spatial divisions of labor form in cities that isolate such residual
low-income workers (and other segments of workers) in their own communities to be socially reproduced and deployed. The end result is the creation of mosaics of communities—ghettos, working-class neighborhoods, middle-class districts, upper-income enclaves—that reflect the actions of complex institutional operations working through the structural logic of creating packets of workers on landscapes.

This stratification—essential to reproducing local labor—is sustained through realtor steering, bank redlining, government constructing low-income social spaces, and the like. While these actors do not conspire to promote residential differentiation, the short-term pursuit of profit collectively has this effect. Space, as a socially constructed apparatus, encourages labor slot reproduction into future generations. Every segregated social group operates within a kind of daily prism that, for ghetto residents, closes into a prison of space and resources. In this way, individuals inadvertently carry an imprint of a given environment, even under conditions of active contemplation and reflexiveness, as they engage a daily-life environment that acts to transmit inequalities.

David Wilson

See also Ethnic Segregation; Housing and Housing Markets; Poverty; Race and Racism; Racial Segregation; Segregation and Geography; Urban Geography; Urban Spatial Structure; Urban Underclass

Further Readings


Anthony Giddens is one of the most influential social theorists of the late 20th and early 21st centuries and the inventor and most prominent proponent of the theory of structuration. He was also a leading figure in British “third-way” politics in the 1990s. He has published at least 35 books, which have been translated into 30 languages, and more than 200 articles. Within human geography, he played a key role in debates about the “new regional geography,” the emergence of critical human geography, and theoretical developments in European social geography.

Giddens was born in Edmonton, a working-class area in northeast London. From the mid 1950s onward, he studied, at the University of Hull, Yorkshire, philosophy and sociology under Peter Worsley, an active member of the Socialist Society. He completed his master’s degree from the London School of Economics, where noted theorists such as Karl Popper, Ernest Gellner, Peter Winch, and Ralf Dahrendorf were lecturing at the time. Their theoretical debates inspired Giddens’s interest in social theory, as unveiled in his first book Capitalism and Modern Social Theory: An Analysis of the Writings of Marx, Durkheim and Max Weber in 1971. He was appointed as a lecturer at Leicester University, where he worked with Norbert Elias and Iliya Neustadt, and he spent several terms at Simon Fraser University (Vancouver) and at the University of California at Los Angeles. In 1969, he was appointed as a lecturer in sociology at Cambridge University, where he worked with Norbert Elias and Iliya Neustadt, and he spent several terms at Simon Fraser University (Vancouver) and at the University of California at Los Angeles. In 1969, he was appointed as a lecturer in sociology at Cambridge University, where he also received his PhD from King’s College, and he cofounded Polity Press in 1985. He was promoted to a full professorship of social and political theory in 1987. Ten years later, Giddens was elected director of the London School of Economics. In June 2003, he was given a lifetime peerage in the House of Lords.

In the 1970s and 1980s, Giddens developed the theory of structuration, which elaborates on classic social theory. Giddens argued that Karl Marx, Émile Durkheim, and Max Weber were all equally important founding figures of modern sociology. These three scientists shared more
similarities than was usually claimed. They all dealt with the emergence of modern society under the influence of industrialism and Western capitalism. Each of them presents specific analytical foci for the study of modern societies. As these foci are rooted in the 19th century, they need critical elaboration if social theory is to keep its relevance for the analysis of late modern societies. This is the starting point of Giddens’s approach, which incorporates three main lines of argument: (1) an ontology of late modern societies, (2) the elaboration of an adequate social theory of late modern societies, and (3) a theory-based intervention in politics as a “third way” between capitalism and communism for the renewal of social democracy.

Giddens’s ontology of contemporary societies reaches the conclusion that social reality changed so dramatically during the 20th century that none of the theories of the classics of social thought can continue to grasp it in a satisfying manner. The two most important dimensions of transformation are the shift from the temporal and spatial embeddedness of traditional societies to the disembeddedness of posttraditional or late modern societies and, based on the processes of disembeddedness, the ongoing process of subjectivation/individuation, implying most of all a radical transformation of intimacy and emancipatory politics. The elaboration of structuration theory, quite different from those of Pierre Bourdieu or Roy Bhaskar, takes the new socio-ontological conditions of late modern societies explicitly into account. Giddens’s approach redefines the relations between agency, structure, and social system. In doing so, he draws attention to the duality of social structures, in other words, to the fact that social structures are constituted by human agency while at the same time they are a medium of social agency, enabling as well as constraining it. Based on this constitutive conceptual frame, structuration theory suggests investigating societies first of all in terms of agency and institutionalized practice and not in terms of structural categories. Accordingly, processes of structuration, that is, the interrelations of agency and (enabling/constraining) structures, should form the center of social research, not simply the analysis of structure.

It is important to note that the use of the terms agency and structure differs considerably from their use in the classics of social theory. Agency as conceptualized in human activities differs from action as conceptualized by Max Weber. Weber’s concept of action was conceptualized in its pure form as a purposive-rational form of social activity, based on a rational consciousness. Giddens’s concept of agency includes also social practices based on a practical consciousness constituted primarily by tacit knowledge. Therefore, agency refers not to rational, goal-oriented activity but rather to a more general steering capability of social practice. Structure, as a form of conceptualizing social relations, differs in Giddens’s theorizing decisively from Durkheim’s and Marx’s theories. Giddens does not interpret structure in a static and deterministic way but rather as the medium of action, enclosing the core elements, rules, and resources. Rules denote guidelines of conduct as well as schemes of interpretation that enable the understanding of the culturally specific meanings of the activities of human agents and of sociocultural events. Resources refer to the capability of control over the object world, the means of production, and nature (allocative resources) and to the capability of control over (present and absent) persons (authoritative resources). The varying degrees of control thus display the differing power potentials of the agents.

According to Giddens, the social world is constituted by every concrete interaction. Agency referring to social structures then constitutes structuration processes in the sense of reproducing and transforming social reality. Structure and agency are neither the same, nor can they be regarded as dualistic (i.e., as two separate entities); but rather, they should be regarded as a duality, that is, deeply interwoven with one another. They are two aspects of the same thing, that is, social praxis. Social praxis should then be understood as simultaneously structuring and structured by human agency.

Benno Werlen

See also Critical Human Geography; Pred, Allan; Structuration Theory; Thrift, Nigel; Time-Geography
Further Readings


**GILBERT, GROVE KARL**

(1843–1918)

Time and space represent perhaps the two most fundamental inputs to the explanation of landscape development and differentiation. In traditional qualitative models, time is the preeminent variable. However, if the landscape and/or its constitutive elements reflect some sort of instantaneous balance between the forces acting on it, or them, and surface resistance, then we are offered a fundamentally different starting point from which to examine their development. Geomorphological models dominated by a temporal perspective have been largely biological in tone; however, Grove Karl Gilbert, a contemporary of William Morris Davis, viewed landscapes from the perspective of physics and engineering. The great contrast between the two approaches is that a Davisian approach results in a time-dependent model of development, while that of Gilbert favors time-independent modeling. In the former, spatial variation is essentially a form of contamination; in the latter, time, be it absolute or relative, contaminates. Clearly, both time and space must be considered; however, the relative weight assigned to each influences the resulting perspective enormously.

Gilbert received enormous professional recognition while alive; however, his professional life followed a very different path from that of Davis. Working for the U.S. Geological Survey, he served as an administrator for lengthy periods. He also was not apparently very interested in integrating his ideas into a comprehensive model of landscape development. Finally, his profound commitment to physical and engineering principles did not resonate greatly with the dominantly qualitative and biologically inspired views of the time. Consequently, his enormous insights, while lauded during his professional lifetime, lay fallow for a long time after his death. It was not until the 1960s that John T. Hack reinvigorated Gilbert’s legacy when he invoked it as the foundation for his own ideas of dynamic equilibrium.

Present-day geomorphology would not be what it is without Gilbert’s seminal paper “Report on the Geology of the Henry Mountains.” Among Gilbert’s many important conceptual contributions are “the law of uniform slope,” “the law of structure,” “the law of divides,” and “the tendency to equality of action, or to the establishment of dynamic equilibrium.” He also produced important methodological papers that may be seen as the clear forerunner of the concept of “multiple working hypotheses,” more commonly associated with its later formulation by T. C. Chamberlin.

*Colin Edward Thorn*

See also Davis, William Morris; Geomorphic Cycle; United States Geological Survey (USGS)

Further Readings

Environmental process models describe the exchange of energy and materials through space and time and assess their impact on the environment. Many environmental process models are closed monolithic systems that cannot be easily modified. When dealing with increasingly complex environmental problems, multiple models are often involved in a single project, but only parts of each model are relevant. An ideal approach is to integrate only the relevant parts into a customized model or an interoperable model.

The interoperable modeling approach may fundamentally change the way environmental models are developed and used, as well as the way they integrate with geographic information systems (GIS) and other tools. This development is supported by both the research community and government agencies and is foreseen as an inevitable direction for future generations of environmental process models.

Interoperation allows data and functions to be used freely across systems. At the core is the semantic interoperability, which allows for meanings of data and functions to be shared between users. Computing techniques are already available to support interoperable models, such as component-based modeling. Components are independently developed, ready-to-use software units. They can be assembled to form functional systems. The challenges lie in the conceptual issues, including the principles to guide the delineation of components, the meta-information needed to describe a component, and the semantic compatibility between components.

The first issue is to identify the primitive components, the building blocks of an interoperable model. Because the existing process models embody accumulated knowledge and time-tested coding, it is sensible to respect these developments and identify the common elements contained in them in order to delineate the primitive components. The semantic reference system can serve as a conceptual framework to guide the delineation. This system consists of (a) a semantic datum that contains the most basic terms and their meanings, (b) a semantic reference frame that organizes the semantic datum, and (c) translation functions that relate a concept in an application to the semantic reference frame and annotate the concept by the semantic datum.

Methods such as formal concept analysis can help translate the concepts (e.g., equations, processes) in heterogeneous environmental models to the discipline datum, identify the common elements embedded in the local concepts, and subsequently identify the primitive components.

Several types of meta-information are needed to describe a primitive component. One type is spatial and temporal scale, such as spatial and temporal continuity (i.e., discrete vs. continuous), spatial and temporal extent, and spatial and temporal resolution. Another type of information is the scale of processes, represented as entity hierarchy, process hierarchy, and the relationships within each and between them. A third type of information addresses parameters and their values for environment conditions, initial conditions, and boundary conditions. The fourth type is concerned with model development, such as information about model creation, validation, and referencing.

The third issue, semantic compatibility between components, addresses whether environmental process components can be assembled together. The meta-information associated with each component is critical for this step. A number of approaches can be used to evaluate the semantic similarity between components. These include trees and conceptual graphs and associated methods to evaluate compatibilities.
GIS, HISTORY OF

Geographic information systems (GIS) benefited from a range of parentage disciplines. The advent of spatial information management and decision support systems can be traced to a range of development push disciplines, including transportation engineering, automated cartography, computer science, aerospace engineering, and remote sensing. A litany of disciplines further created the applications environment for these systems to succeed, including demography, agricultural science, forestry, urban and regional planning, ecology, rangeland management, and geography. Common to these push and pull disciplines was the influence of 1960s space age technology and the computerized information age. Two decades of GIS development occurred prior to geographers formally recognizing GIS as a field in geography. Geographers began in the 1980s to investigate the underlying scientific principles and the framework for the success of these automated spatial information systems. At the turn of the 21st century, GIS became prevalent throughout society, and usage expanded exponentially among the general public, with Web-enabled facilities for viewing any location on Earth or easily selecting optimal routes for travel destinations anywhere on the planet. Virtual worlds on the Internet, or digital Earths, can be directly traced to the pioneering work of a finite set of individuals and laboratories, predominately located in North America.

Further Readings


Conceptual Landscape

The prowess of spatial analysis had been recognized for millennia in the use of maps to illustrate records, beginning with petroglyphs of optimal hunting areas and extending to Sumerian clay tablets for agricultural and land taxes. Mercator’s map projections provided the first global standard for cartographic representations and hence can be viewed as one of the first “systems” for geographic information. Prior to the age of automation, examples of using overlay maps (i.e., space) to depict different object themes or time sequences for a geography were demonstrated in 1781 in the “Siege of Yorktown” sketches by Louis Alexandre Berthier (and the 1874 Louis van Blarenberghe painting based on the sketches) and in 1838 for the *Atlas to Accompany the Second Report of the Irish Railway Commissioners*. In 1912, the benefits of spatially overlaid maps were documented for both thematic maps of Billerica, Massachusetts, and time series maps of Düsseldorf, Germany. Spatial data overlay mapping methods were proving to be valuable analytic tools for large landscape projects. In 1969, Ian McHarg’s seminal book *Design With Nature* formally introduced to a national audience of landscape architects and thoughtful managers the comprehensive power of systematic spatial analysis using transparent Mylar overlay maps for human development design and engineering. It remained for the influence of automated methods in the 1960s to establish the quantitative framework for the genesis of computer-based GIS.

Technology Prerequisites

Technology was a paramount factor in the creation of modern GIS, beginning with the confluence of Herman Hollerith’s Census Bureau’s data and command language punch cards operating on electronic computers from the postwar era of the late 1940s. Translating geographically referenced data, or geodata, into computers required many
inventions to facilitate this basic need. Geocoding techniques using Cartesian reference systems were required to keep links of data to geography. Database methods were created to capture the georeferenced files using various schemas. Manually typing in these records proved to be an onerous task, and capturing irregular grid-shaped features from maps necessitated scanners to digitize data, both from drum-based and from flatbed technologies, to create vector files. Visually displaying the results required the advent of cathode ray tubes (CRTs) to project maps and their layers. Collecting data for larger areas traditionally relied on aerial photographs (analog format) that were manually annotated and then digitally scanned (vector format). Digital remote sensing tools, beginning in the 1970s with the Landsat series of satellites, provided raster data format. Computer scientists created a variety of algorithms to frame the schema used to collect, store, and manipulate the digital data. Innovators designed and built automated systems to handle the challenges of acquiring spatial information and subsequently printing maps using the rapidly evolving computational tools of the space age. This progression followed the quantum leaps in computing power, beginning with large mainframe computers and leading up to laptops and field-portable, handheld display phones, enabling GIS mapping information to be transported anywhere on the globe.

**Pioneering Centers**

Government organizations were the main agents responsible for collecting, analyzing, and managing large volumes of land ownership and census records, often in collaboration with universities, which were keen to attempt creative approaches to automating the increasingly large records. Roger Tomlinson led the development of the Canadian GIS in the 1960s and is credited with establishing the first operational automated spatial information system, as well as with coining the GIS moniker for these technologies. Tomlinson’s team automated Canada’s natural resources information files for a number of thematic data layers for the purpose of reading digitally encoded maps, to then measure, compare, combine, and analyze the data for useful decision making. To encode map data, the flatbed digitizer, Morton Matrix tiling structure, and geocoding coordinate system methods were created for this pioneering system. Basic data manipulation and retrieval commands and algorithms were created that enabled the earliest automated spatial analysis, including topological overlay. These fundamental elements remain the foundations for vector GIS software.

During the same period, the U.S. Census Bureau was addressing the requirements for automated address matching. Working with a network of New England organizations, the Census introduced data structure models and methods for computer mapping and small-area data analysis with address-matching data, which led to DIME (Dual Independent Map Encoding) in 1967. DIME can be viewed as the information fuel that fed many of the early state and local GIS developments throughout the 1970s. DIME was promulgated via the 1967 URISA (Urban and Regional Information Systems Association) conference and the New Haven Census Use Study of the same year, whereby recognition of its topology functions for address location and analysis influenced further developments at the Harvard Laboratory for Computer Graphics. The Harvard Lab served as a unique incubator for the modern GIS landscape. Harvard’s Center Laboratory for Computer Graphics invented GRID, which begat Odyssey and then SYMAP, which was used to form both Synercom and Intergraph corporations. A separate path from Harvard was the creation of Arc/Info and ESRI, Inc. (Environmental Systems Research Institute). ESRI and Intergraph are market leaders in the 21st-century GIS and computer-aided drafting (CAD) industry. Other academic centers that were also seminal incubators of conceptual models, software systems, and young pioneers include the University of Washington, University of Oregon, Purdue University, University of California (UC) at Berkeley and at Santa Barbara, Pennsylvania State University, and University of Wisconsin.

Raster-based GIS was borne of two major paths that can be traced to the use of grid (matrix) data structures for land records and the development research for remotely sensed data and engineering systems, more commonly called remote sensing. Raster and vector data formats are inherently different structures for storing spatial information. Notable early pioneers for raster-based GIS included the Minnesota Land Management
Information System (1967–1971), the Land Use and Natural Resources Inventory of New York State (LUNR, based on Harvard’s SYMAP), and the Oak Ridge Regional Modeling Information System (ORRMIS), started in 1970. The Harvard Lab also developed the first interactive geographic analysis tool, IMGRID (Interactive Manipulation GRID), considered the forerunner of all raster GIS, including Map Analysis Package (MAP). Image-processing systems also handled the manipulation of raster data for the remote sensing (airborne and satellite) community. The National Aeronautics and Space Administration (NASA) worked in collaboration with a variety of centers, such as UC Berkeley, Jet Propulsion Laboratory/Cal Tech, University of Michigan (Environmental Research Institute of Michigan), University of Kansas, and Purdue University (Laboratory for Agricultural Remote Sensing). NASA funding supported many early raster systems, including VICAR/IBIS (Jet Propulsion Laboratory) and LARSYS (Purdue). Industry also created systems for mineral exploration and forestry, such as IDIMS (ESL, Inc.), MDAS (Bendix Corporation), Image 100 (General Electric), and ERDAS (ERDAS, Inc.).

GIS vendors of this century offer systems that easily handle vector and raster data structures, with interchangeable data formatting that makes many of the early distinctions moot. However, the development pathways for these systems were fundamentally separate until the late 1980s.

Other pioneering efforts were evolving in the 1970s outside North America, as demonstrated in centers such as the Experimental Cartography Unit of the Royal College of Art in the United Kingdom and the Commonwealth Scientific and Industrial Research Organization in Australia and the work led by Chen Shupeng at the Chinese Academy of Sciences. While no commercial ramifications of these efforts can be documented, important research applications furthered understanding of automated mapping and cadastral systems as well as assessment methods for disaster and humanitarian response.

### Fuels for Development

The bane of early GIS operations, often heard in the laments of technicians and graduate students, was the labor-intensive nature of digitizing data for input into the automated spatial databases. With the onset of flatbed free-cursor digitizing tables (a result of Ray Boyle’s contribution to the Canadian GIS), long hours were required to translate the lines, points, and polygons from paper or Mylar maps into computer records. Alternatives to this laborious and error-prone method were well received and were responsible for the rapid increase in commercial acceptance of the early vendor software packages. Beginning with the digital DIME files, GIS users could now rapidly build large-area databases with street centerlines to define the geography along with spatial encoded knowledge (i.e., topology) of street ranges, left and right, and directionality. This fuel for GIS can be credited in large part for the expanded user base, an exponential curve that began in the 1980s. The Census Bureau’s upgrade to these digital data files for the 1990 census was TIGER (Topological Integrated Geographic Encoding and Referencing). Digital TIGER files for the nation were demonstrably the fuel for business applications with GIS.

A second pathway that fueled GIS development and applications was the NASA/U.S. Geological Survey Landsat series of satellites. With Landsat digital raster data, large areas of the landscape, over 9 million acres per image scene, were captured with a pixel resolution of 1.1 acres. Land managers, biologists, foresters, and mineral scientists could use Landsat data to populate land management GIS for myriad applications with timely and precise digital input. Topology for raster systems is inherent in the Cartesian matrix of the gridded data structure and has proved to be extremely valuable in determining questions of adjacency, buffers, and best-route analysis. Systems such as ERDAS were early pioneers in desktop computer systems using raster-based systems with digital satellite data. Without the TIGER and Landsat digital data fuel, GIS growth in the commercial markets would have been significantly set back in time.

### Mainstream Implementation

Canada’s GIS paved the way for cost-effective automated inventory and data management approaches for agencies entrusted with large-acreage stewardship. In the United States, the
impetus for automated GIS was borne out of state governments’ requirements for planning and natural resources inventory systems. Many of these initiatives were stimulated further by the federal government’s 1969 National Environmental Policy Act (NEPA). NEPA’s mandate clearly required a new level of awareness by federal and state agencies regarding mitigation of environmental impacts. Early GIS developments included the Maryland Automated Geographic Information (MAGI), the Minnesota Land Management Information System (MLMIS), New York’s Land Use and Natural Resources (LUNR), the Ohio Capability Analysis Program (OCAP), North Carolina’s Land Resources Information Service (LRIS), and the Arizona Land Resource Information System (ALRIS). The influence across a broad sector of government and scientists of the natural resource inventory systems development efforts of the late 1970s and early 1980s cannot be overstated. These pioneering system implementations incorporated government agencies, vendors and consultants, and university researchers who created careers, new technology, and new policies for land management through trial and experiment, setting the framework for the commercial successes of the 1980s, the maturing decade of the best-known modern GIS.

The engineering world of automated mapping and facilities management (AM/FM) quickly matched the GIS systems development, but for a distinct class of engineering stakeholders. Computer-aided drafting and mapping (CAD/CAM) did not possess topology but was responsible for many developments in 2D (two dimensional) and 3D visualization that hybridized GIS software systems quickly adapted.

The latest chapter in GIS history is exemplified in the visual rendering of spatial information on virtual globes or Earths. Geographically referenced tessellation engines, or geobrowsers, became visible beyond research centers and NASA’s Digital Earth initiative and came into the public view in the early 2000s. GIS functionality became increasingly popular with users of Web-based platforms, beginning with 2D mapping viewers in Mapquest and extending to 3D with Google Earth. Simple as well as sophisticated GIS analytic tools are available for a host of virtual Earth geobrowsers, including NASA’s WorldWind, Microsoft’s Virtual Earth, ESRI’s ArcGlobe, GeoFusion’s GeoMatrix, and Google Earth. GIS capabilities to query, conduct analysis, and generate useful maps and data are available anywhere on the globe with access to the Internet. This represents a truly remarkable geographic revolution over the past four decades.

Timothy W. Foresman

See also Batty, Michael; Business Models for Geographic Information Systems; Critical GIS; Dangermond, Jack; Egenhofer, Max; Fisher, Peter; Frank, Andrew; Geodemographics; Geodesy; Geographic Information Systems; Geoslavery; Geospatial Industry; GIScience; GIS in Archaeology; GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Land Use Management; GIS in Local Government; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; GIS Software; GIS Web Services; Goodchild, Michael; Google Earth; Humanistic GIScience; Tomlinson, Roger; University Consortium for Geographic Information Science

Further Readings


GIScience (geographic information science) is a scholarly discipline that addresses fundamental issues surrounding the use of a variety of digital technologies to handle geographic information, namely, information about places, activities, and phenomena on and near the surface of the Earth that is stored in maps or images. GIScience includes the existing technologies and research areas of GIS (geographic information systems, or
GIScience therefore includes questions of spatial data structures, analysis, accuracy, meaning, cognition, visualization, and many more and thus overlaps with the domains of several traditional disciplines that are concerned with Earth’s physical processes and how humans interact with the Earth (e.g., geography, geology and geophysics, oceanography, ecology, environmental science, applied mathematics, spatial statistics, physics), as well as disciplines that are concerned with how humans interact with machines (e.g., computer science, information science, cognitive science, cognitive psychology, artificial intelligence). However, GIScience is not central to any of these fields, representing instead a new kind of scientific collaborative that is defined by researchers from many distinct backgrounds working together on particular sets of interrelated problems, problems that are not only scientific in nature but also serve the needs of natural resource management, government, industry, and business.

It is important to make a distinction between GIS and GIScience. While GIS is concerned primarily with the hardware and software for capturing, manipulating, and representing geographic data and information (e.g., as a container of data, maps, and software tools), GIScience is essentially the “science behind GIS” or the “science behind the systems.” It can be defined further as the scientific research that is done both on and with GIS, ranging from the fundamental issues arising from the use of GIS (e.g., how to improve the interface to the system, improve its overall design and usability, or track error through the system) to the systematic study of geographic information using scientific methods (i.e., methods based on issues of scale, accuracy, and quantitative analysis of spatial data) and even to the science that is done with GIS (e.g., the development of spatial models for predicting landslide susceptibility in a region, agent-based models for simulating the actions or interactions of vehicles in a transportation network, or a map, table, or spatial statistic expressing the environmental impacts resulting from the decision to commercially develop a piece of land).

A Brief History of GIScience

The origin of GIScience is traced back to two keynote addresses presented by Michael Goodchild of the University of California at Santa Barbara at conferences in Europe: one titled “Spatial Information Science” (to the Fourth International Symposium on Spatial Data Handling, Zurich, Switzerland, in July 1990) and the other, “Progress on the GIS Research Agenda” (to the Second European GIS Conference, Brussels, Belgium, in April 1991). In both of these keynote addresses, Goodchild challenged the academic GIS community to move beyond a focus primarily on the technical capabilities of GIS to the more substantive intellectual challenges and scientific questions posed by the use of GIS or by the impediments to its use. This fundamental shift would thereby ensure the acceptance and longer-term survival of GIS within broader academia. These important presentations were later published in 1992 in a seminal paper for the International Journal of Geographic Information Systems, a paper that has since defined the field of GIScience. In 1988, a few years prior to Goodchild’s presentations in Europe, the National Science Foundation (NSF) awarded a multiyear, multimillion-dollar grant to the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine to form the National Center for Geographic Information and Analysis (NCGIA). This was the first major consortium of academicians formed to define and conduct research in the field, laying the foundation for current and future scholarly inquiry by way of its Initiatives 1–21 on topics ranging from the accuracy of spatial databases to visualization of spatial data quality, to the social implications of GIS, to the multiple roles of GIS in global change research, to collaborative spatial decision making. Following on the success of the NCGIA, but
seeking to realign its research, education, and outreach agendas on the more basic, fundamental issues of GIScience, the NCGIA spawned Project Varenius in 1997. Project Varenius focused on several strategic areas of GIScience deemed among the most fruitful for advancing the field in the new context of 21st-century information technology. These strategic areas were cognitive models of geographic space, geographies of the information society (including spatial data infrastructures), and computational implementations of geographic concepts (including overcoming the duality of spatially continuous fields vs. discrete objects). A series of Varenius specialist workshops were held on these topics, generating publications from 1997 to 1999.

In a somewhat parallel effort, in 1990 the NCGIA board of directors recommended that a more broadly based organization be established to engage the long-term participation of excellent researchers beyond the three-university consortium of the NCGIA, thereby supporting and promoting GIScience even further. The NCGIA responded by forming an ad hoc committee of researchers from 16 institutions with prominent programs in GIS and representing seven different academic disciplines. These individuals gathered sufficient momentum to spawn a national meeting in Boulder, Colorado, in 1994, which was attended by 42 individuals representing 33 universities, research institutions, and the Association of American Geographers. This meeting established the University Consortium for Geographic Information Science (UCGIS) as a formal nonprofit organization charged, as indicated on UCGIS's Web site, with “advancing the understanding of geographic processes and spatial relationships through improved theory, methods, technology and data, and to promote the informed and responsible use of geographic information systems and geographic analysis for the benefit of society.” The UCGIS has since grown to a membership of more than 80 (as of 2008, 73 universities, three professional organizations, and eight corporate, government, and international members). The organization continues to seek ways to unify the academic GIScience research and education communities to speak with a strong voice on matters affecting resources and policies, particularly where the U.S. Congress and federal agencies such as the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S Geological Survey (USGS), the National Geospatial-Intelligence Agency (NGA), the Federal Emergency Management Administration (FEMA), the Department of Homeland Security (DHS), and the National Oceanic and Atmospheric Administration (NOAA) are concerned. Over the years, the organization has formulated dozens of research and education priorities in GIScience; disseminated these via white papers, brochures, and occasional scholarly monographs; and assessed progress in relation to major federal programs and national interests.

In Europe, a similar effort was launched to form the Association of Geographic Information Laboratories for Europe (AGILE). AGILE was established in 1998 with a mission and goals similar to those of UCGIS and with an eye toward continuing momentum from the European GIS conference series, as well as new research initiatives developing within the European Science Foundation’s GISDATA scientific program. AGILE promotes and develops GIScience initiatives in a manner similar to UCGIS, with working groups, research initiatives, and small conferences and workshops for the exchange of ideas and strategic planning on promoting GIScience initiatives.

GIScience as a field of study has now reached a mature level, with its own scholarly journals, research monographs, blogs, textbooks, core curricula, degree and certificate programs, research institutes, professional organizations, and conferences. For example, in addition to the UCGIS and AGILE, there are related organizations such as the Cartography of Geographic Information Society, the Open Geospatial Consortium, and the International Spatial Accuracy Research Association and leading peer-reviewed journals such as the International Journal of Geographical Information Science and Cartography and Geographic Information Science as well as Transactions in GIS and Geoinformatica. The GIScience series of conferences has convened biennially since 2000, and several new conferences that have emerged in recent years, such as GeoWeb, the International Conference on Geospatial Semantics, and the Where 2.0 and OSCON conferences of O'Reilly Media, now regularly feature GIScience themes and research topics.
Examples of Research Topics in GIScience

Research in GIScience is now represented by literally scores of different topics and specialties, all arising from the questions raised by GIS and the other kinds of geographic technologies mentioned above. For example, there are questions of representation. How should the varied and infinitely complex features on the surface of Earth be represented? What criteria should be used to select a representation? How can a representation be best assessed in terms of its accuracy and completeness? How should one store a given representation efficiently—what is the best data model to use conceptually and the best data structure to use computationally? How should a representation be extended from the well-known two dimensions of a flat surface to the three, four, and $n$ dimensions needed to capture and understand dynamic processes in the atmosphere, in the ocean, and on Earth’s surface?

There are research questions in the realm of scale, which refers to the level of detail at which information can be observed, represented, and analyzed. How does changing the scale of data affect our understanding of the processes or patterns generating the data? Do processes always scale linearly or uniformly, and if not, how do we characterize or understand them? What are the best ways to describe scaling behavior? Should one use a fractal dimension or multifractals? Is there scale within the digital world of the computer (i.e., does a cartographer’s representative scale for a paper map really matter for data sets that may never exist in paper map form)?

Research questions abound in other areas, such as spatial data acquisition and integration, cognition of geographic information, interoperability of geographic information, spatial information policy and privacy, error and uncertainty of spatial data and analyses, and many more. Table 1 summarizes the many interesting areas that have persisted in GIScience as well as those now emerging. Most of these have been identified and refined by the UCGIS over the course of their summer and winter assemblies of the past decade. Of note once again is that these do not focus on geographic technologies such as GIS, GPS, remote sensing, and so on but on several fundamental issues raised by the technologies, especially those impeding its more effective use. The science done with the technologies is motivated by the need for improved practice, observation, and spatially explicit problem solving.

Education in GIScience

As the adoption of GIS technology and the principles of GIScience have continued to increase across academic, government, and commercial sectors, there has been an increasing emphasis on ensuring an adequately trained and educated workforce in GIScience. Each year, the demand by university students for courses not only in GIS but also in GIScience has increased, as has the demand for this coursework by geospatial professionals. Furthermore, the advances in the technology and the research have spawned a national demand for sequences of courses external to traditional degree programs, hence the proliferation of certificates in GIS, in remote sensing, in surveying, and the like. In the late 1990s, it became the view of many professionals within the GIScience community that the time had come to synthesize, articulate, and put into appropriate intellectual context the recent advances of this research for use in the classroom at both the undergraduate and the graduate levels. As such, the UCGIS developed a set of national priorities to advance GIScience education. Among these was a focus on emerging technologies for delivering GIScience education, including distance education (e.g., the Web, multimedia audio and video files, digital libraries, tele-immersion, digital video, Internet2, and distributed classrooms connected by digital audio and video for two-way interactive lecture sessions). Supporting infrastructure to support GIScience instruction was a related priority, covering issues of facilities administration and staffing, design and maintenance, safety and security of labs and classrooms, and financial resources. Other priorities included access and equity issues (e.g., for students with physical or learning impairments or those from disadvantaged or disenfranchised groups of society), alternative designs for curriculum content and evaluation, research-based graduate GIScience education, and learning with GIS (emphasizing the use of both GIS and GIScience to help students learn about other subjects, such as environmental science).
Soon after developing its national education priorities, the UCGIS embarked on an ambitious project to develop visionary model curricula for GIScience, designed to further aid in the development of an adequate supply of well-educated and well-prepared GIScientists and technologists. Desired outcomes of a model curriculum included the following: (a) demonstrated skill in integrative spatial thinking and effective implementation of various spatial analysis methods, as well as collaborative learning across several subdisciplines within the GIScience field; (b) solid grounding in the appropriate application of related geospatial technology (software, data collection instruments and devices); and (c) familiarity with a wide variety of research applications, management, and decision support scenarios, with the capacity to apply knowledge to scientific and management problems at a variety of spatial and temporal scales.

Over an 8-yr. (year) period (1998–2006), dozens of GIScience researchers and educators participated in workshops and related activities to develop an initial comprehensive inventory of knowledge and skills defining the field. The result was the first edition of the GIScience & Technology Body of Knowledge resource book and brochure, published in 2006 and detailing hundreds of topics and thousands of formal educational objectives, all organized into more than 70 units within 10 major knowledge areas.

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Table 1  Examples of high-priority research topics of GIScience
Source: Based on information from the University Consortium for Geographic Information Science and the Association of Geographic Information Laboratories for Europe.
The Body of Knowledge serves not only as a resource for course and curriculum planning but also as a basis for professional certification, program accreditation, and articulation agreements between 4-yr. universities and 2-yr. community colleges. Issues of certification where GIScience is concerned and, to a lesser degree, accreditation and licensure will be the subject of vigorous discussion and debate in the foreseeable future. As yet, there is still no authoritative body that accredits a GIScience major, minor, or certificate program, as currently exist for engineering, urban planning, architecture, and other professionally oriented programs (keeping in mind that accreditation refers to programs to establish professional and ethical standards, whereas certification refers to individuals). This differs from licensure, which is meant to protect the public from any harm that an incompetent professional may cause (e.g., as is the case with the licensing of land surveyors). Organizations such as the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology accredit traditional disciplines such as civil engineering and forest engineering. But these organizations are highly disciplinary in orientation and commonly review entire departments or colleges rather than their components. The Urban and Regional Information Systems Association (URISA) piloted a national program in 2003 to certify GIS professionals via a new GIS Certification Institute (GISCI), including an ascription to a GIS code of ethics. GISCI produced the first group of certified GIS professionals (GISPs) in 2003 and has since certified over 2,000 more by way of a nonexamination, portfolio-based system. GIScience coursework offered throughout the United States supports eligibility for this national certification. The American Society for Photogrammetry and Remote Sensing certifies a range of GIScience professionals (mapping scientists and technologists in GIS/land information systems, remote sensing, and photogrammetry) via a peer-reviewed application and written-examination system.

*Dawn J. Wright*

*See also* Analytical Operations in GIS; Association of Geographic Information Laboratories for Europe; Critical GIS; Geocomputation; Geographic Information Systems; Geospatial Industry; Geoslavery; GIS, Environmental Model Integration; GIS, History of; GIS Design; GIS Software; Goodchild, Michael; Google Earth; Humanistic GIScience; Neogeography; Spatial Analysis; Spatial Data Models; Three-Dimensional Data Models; University Consortium for Geographic Information Science

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**Further Readings**

Association of Geographic Information Laboratories for Europe: www.agile-online.org


GeoWeb: www.geowebconference.org

GIScience series of conferences: www.giscience.org


O’Reilly Conferences: http://conferences.oreillynet.com

University Consortium for Geographic Information Science: www.ucgis.org


GIS DESIGN

Geographic information system (GIS) design refers to a process of developing a spatially explicit computer information system to provide a simplified representation of geographical entities and phenomena and support relevant spatial analyses. Since its formative years in the 1960s, GIS has experienced rapid progress in its capacity to handle spatial information, and it has become a powerful research tool for various study fields inside and beyond the discipline of geography. For example, GIS has been widely used in agriculture and land use planning, natural resource management, transportation, geology, municipal applications, and business, among others. These application domains have quite different requirements in spatial modeling and analysis. A GIS design process aims at helping system developers identify unique data needs and develop an effective model to support data analyses.

A GIS comprises five key components: data, people, hardware, software, and procedures. Geographic data, which include both spatial information and nonspatial attributes of geographic entities, are considered as the most important component of GIS. They are often stored and maintained in a database management system (DBMS) and provide the basis for data query and spatial analysis. The people component covers a wide variety of individuals who are related to a GIS application at different levels. They can be GIS professionals who design, develop, and manage the system; general GIS users who use the system to complete their everyday work; or geographic data viewers who simply browse a GIS database occasionally for information. The hardware component consists of equipment that supports the operation of a GIS application and other devices that facilitate the input/output of geographic data (e.g., global positioning system [GPS] data loggers, digitizing tablets, scanners, and plotters). The software component refers to computer programs and user interfaces that provide for the spatial data handling capabilities of the system. Finally, procedures define the specific steps of manipulating and analyzing the geographic data to solve domain-specific application problems. All five components interact with one another to form a functioning system. Therefore, an effective integration of these components is paramount to creating a successful GIS application. A GIS design process can help ensure the effective integration of the components in a specific application domain by identifying the domain-specific requirements and incorporating the components to meet the application data-processing needs. Similar to the development of other information systems, a GIS design process follows standard steps. In general, these steps include identifying and analyzing user information needs, defining the system scope, making choices about data and database models, determining the system requirements, and, finally, implementing the system.

User needs analysis, which is the first step in developing a GIS application, presents an important task to help system developers understand the purpose of a proposed system. As each GIS application is created to support spatial decision making in a particular problem domain, there are specific requirements to integrate the five GIS components. System developers need to examine the following questions: Who are the end users of the system? Do they all share the same needs? If not, how many different user groups are there, and what are the major functions demanded by each user group? What are the final information products of the system? Detailed answers to these questions can provide proper guidance for the application development.

After the user needs and the goals of GIS applications have been identified, the results need to be further organized and processed to define the system scope. At this stage, developers pinpoint all the data needed in the application (e.g., socioeconomic data, environmental data, political boundaries) and address the corresponding hardware/software requirements to support the data collection and storage. A master input data list is compiled to enumerate all the data sets that are necessary to produce the information products identified in the application. The list contains detailed information of each required data set, including its name, source, spatial reference (scale, datum, and coordinate system), temporal characteristics, size, and cost. The information will guide the effort of creating an effective database design to manage the data in a later step. Since a wide variety of data sets could be used in
a GIS application, some data sets may require specific hardware/software configurations to facilitate the data input process. For example, a digitizer, scanner, or GPS receiver may be used to collect the data, and corresponding software procedures will be used to enter the data into the system. Therefore, it is necessary to evaluate the appropriate hardware configurations and functions to support the data input of the data sets.

Selecting a proper spatial data model for a GIS application is the next important step in GIS design. Different models may be needed to effectively represent and analyze geographic entities and processes in different application domains. Over the years, geographers have developed two fundamental views of geographic entities and processes, viewing them as either discrete objects or continuous phenomena. Accordingly, two representation approaches have been developed. The object-based approach views the world as an empty space populated with discrete geographic features, such as wells, buildings, roads, and administration units, and represents them as objects with well-defined boundaries. Each object can have multiple attributes to describe its nonspatial characteristics. The field-based approach views the world as composed of entities and phenomena that are distributed continuously across space, such as elevation and precipitation, and focuses on representing the transitional variations of a geographic phenomenon across space. In general, the object-based approach is chosen to represent man-made features, since they usually have well-defined boundaries. For modeling natural features, the object-based approach can be used to describe objects with distinguishable boundaries, and the field-based approach can represent features with fuzzy boundaries and gradually changing characteristics. According to the specific requirements of a GIS application, one or both views could be adopted to model geographic entities and processes.

The vector data model, which uses sets of coordinates to record the shape and locations of geographic features, provides a straightforward implementation of the object-based view. In this model, geographic coordinates are directly used to record spatial information and construct three basic geometric types: points, lines, and polygons. These geometric objects then are used to represent discrete geographic features (e.g., landmarks as points, streets as lines, and water bodies as polygons). Depending on specific spatial modeling purposes, various versions of the vector data model have been created. For example, an early vector data model called the spaghetti data model stores geometric elements as unstructured data and provides a simple but effective approach to cartographic representation of geographic features. However, because of the lack of topological information, it has very limited capability to support spatial analysis. To address the limitations of the spaghetti data model, topological data models have been developed. For example, the arc-node data model maintains the topological relationships (e.g., containment, adjacency, and connectivity) of geographic features, besides their locations and shapes. This model is needed if an application requires network or adjacency analysis.

The field-based view focuses on the spatial variations of one particular phenomenon and requires a continuous representation of space. Different tessellation methods have been developed in GIS to cover an area and record the spatial variations of a phenomenon. A regular tessellation method usually divides space into an array of rectangular (or more commonly, square) cells. An attribute value is then stored for each cell to represent the variations of the phenomenon. This method is widely known as the raster data model. Some common examples include the digital elevation model (DEM), which stores elevation values in grids that cover an area, and satellite images, which record the spectral data in pixels. An irregular tessellation method, which uses a set of irregular shapes that do not overlap to cover an area, also has been widely used to divide the space. The triangulated irregular network (TIN) representation, which uses a collection of nonoverlapping, irregularly shaped triangles to cover an area and stores attribute data at the nodes of the triangles, represents a well-known irregular tessellation method. Since the triangles consist of nodes (points), edges (lines), and facets (polygons), TIN is a collection of composite features and a specialized type of vector data model.

Selection of a data model for each specific data set should be guided by GIS user information needs, the characteristics of entities and phenomena
GIS DESIGN

represented by the data set, and the data requirements of spatial analysis workflows dictated by specific application domains.

Once the appropriate data models are chosen for spatial data sets, the next step involves choosing a logical data model to structure the data in a database. Since geographic information is composed of spatial (geometric primitives with coordinates) and nonspatial (attributes of geometric primitives) data components, a logical data model needs to handle both components. Currently, three logical data models, including georelational, object oriented, and object relational, are commonly used to manage geographic data. In a georelational approach, spatial data are maintained in files, and attribute data are managed in a separate relational database management system. A unique ID is assigned to each entity, and the ID is attached to a data record representing the entity’s geometry and the corresponding record representing the entity’s attribute. Operations on geographic entities are performed independently of the storage of geographic data. Such an approach limits the possibilities of representing complex geographic entities and their relationships.

Recently, the object-oriented data model has emerged as a new approach in GIS to overcome some limitations of the georelational approach. The object-oriented data model conceptualizes the real-world features as objects and uses various relationships to capture the interactions among the objects. In this model, the concept of object denotes an integrated package that contains geometry, properties, and methods associated with a geographic entity. Thus, the spatial information and attributes of a geographic entity and the operations defining the behaviors of the entity are encapsulated in one object. Also, a hierarchical structure can be constructed to organize objects representing different levels of real-world entities (e.g., states, counties, and census tracts). Through the hierarchical relationship, the properties and methods defined for the objects at a higher level can be inherited and reused by the objects at a lower level. Furthermore, a method in this model can adapt itself to different objects to produce different results or effects. These characteristics distinguish the object-oriented data model from other geometry-oriented models and support a more intuitive approach to the representation of geographic entities and their relationships. However, due to the difficulties in implementing its complex design, the use of the object-oriented approach has been limited. The most recent development in logical data models is the object-relational data model, which implements object-oriented concepts in a relational database environment. By recording spatial data in a binary large-object (BLOB) field in a relational database, this model enables an integrated approach to the storage of spatial and attribute data of geographic entities. The model has many advantages because it combines the features of both relational and object-oriented approaches. Due to the ease of its implementation, the object-relational data model has become the dominant logical data model for various GIS applications.

Another step in GIS design involves determining the system requirements. This step usually accompanies the selection of data models. In this step, system designers will identify functions that are crucial to the workflows for processing the data to produce the final information products. Based on data-processing requirements, the designers will select software programs (e.g., DBMS and spatial analysis packages) that can provide the needed functionality and choose hardware components (e.g., computers, Web servers, and network connections) that provide the data-processing performance required for the application at hand. Also, if there is no existing software package that can provide the needed functionalities, customized programming will be required to achieve the functionalities.

The final step of GIS design is system implementation. After procurement of the required data, software, and hardware, all GIS components are integrated to build a functioning system. When developing a large and complex system, a prototype system—a mini version of the full GIS system—is usually implemented to test the feasibility of the design before the design is finalized. Also, testing of the full system should be conducted to ensure its functionality, performance, and reliability.

Hongbo Yu

See also Analytical Operations in GIS; Collaborative GIS; Database Management Systems; Data Querying in
GIS IMPLEMENTATION

A geographic information system (GIS) should be considered as an information system rather than as a software product when planning GIS implementation in an organization. Different organizations that implement identical GIS software could experience very different outcomes with respect to their success. An information system involves not only software but also other components, such as data, hardware, procedures, people, and organizational settings. These components must work together to create a successful implementation. As a result, management and organizational considerations are often at least as important as technology in a successful GIS implementation.

Before an organization makes a commitment to GIS implementation, it is critical to identify its business needs and find out if GIS can help the organization meet its needs in more efficient and effective ways. At the minimum, every GIS implementation should begin with a needs analysis that assesses the current and future needs of various units in an organization. Findings from the needs analysis assist an organization in determining if GIS can improve the current system and/or offer new solutions that are not currently available. It is good practice to develop a GIS strategic plan at this stage to provide a framework for managing the changes and challenges associated with introducing GIS into the current work environment.

Once an organization reaches an initial decision of pursuing GIS, the next step is to plan for GIS implementation. The outcome of this implementation planning process should be a well-documented implementation plan that represents an organization’s commitment to GIS and establishes a process and schedule to implement GIS.

One critical component in GIS implementation planning is the system design that identifies the changes needed in an organization to achieve the goals of GIS implementation. System design attempts to address the specific needs related to data, software, hardware, procedures, staff, and organizational issues. With the information collected from a needs analysis, it is feasible to identify the specific products required by various units in an organization, the different kinds of data needed to generate those products, GIS software and hardware with capabilities of supporting different applications, procedures to meet various user needs, trainings for different user groups, and the organizational changes needed to maximize the benefits of GIS implementation.

After identifying the scope of information products and data for a GIS implementation, it is time to consider a GIS database design that attempts to capture and represent the user’s view of specific tasks. For example, a particular user group wants to be able to display maps showing property parcel boundary lines with building footprints based on a user query and to easily identify those properties that are within 1,000 ft. (feet) of each other and have a difference of more than $100,000 in their assessed values. Data available for this particular application may be in different formats, scales, map projections, and geodetic datums. Furthermore, different data sets may be created and maintained by different groups, and they may be shared by several different applications. GIS database design must consider all these factors to choose appropriate logical data models and to design specific physical database schemas to support various user needs. To maximize the benefits of GIS data sharing, it is often necessary to establish standards for data and other related procedures when implementing an enterprise GIS.

Integration and coordination...
communication among various groups therefore play critical roles in GIS implementation.

Workflow is another important consideration in GIS implementation. Data must be processed through specific procedures to generate useful products. A GIS application may involve multiple units with staff of varying levels of GIS knowledge. It is important to consider the workflows in an organization such that the GIS implementation can design user interfaces and procedures to accommodate the business logic behind various applications in a manner intuitive to the users. Once the information about user data needs, application requirements, and GIS database design requirements is collected, a design team can proceed to evaluate alternative GIS software and hardware products and determine which software and hardware configurations will best serve the organization’s needs. A common practice in the selection of GIS software and hardware is to develop functional specifications of the planned GIS implementation and then prepare requests for proposals for vendors to respond with their solutions to the functional specifications. A benchmark test could be included in the evaluation process to help choose among the competing proposals.

One must keep in mind that GIS does not exist for its own sake. GIS is implemented to help people solve problems. In the meantime, people are needed to operate GIS. As a result, people are an integral part of GIS implementation. In fact, most failures of GIS implementation have been attributed to user issues—whether they are due to lack of understanding, lack of coordination, lack of training, or turf wars. It is essential to consider, in a GIS implementation, the technical staff who will manage and operate the system, the potential users who will benefit from the system, and the administrators who manage the system and communicate with decision makers. A successful GIS implementation must communicate with all stakeholders, offer proper training to different user groups, and design an organizational structure to facilitate data sharing and workflows across different units.

Even if an implementation plan suggests that GIS can improve the current system, the costs associated with a GIS implementation may outweigh the potential benefits. Cost-benefit analysis is a method available for an organization to compare the expected costs with the expected benefits before executing a GIS implementation plan. Finally, GIS is a rapidly evolving technology, and user needs may change over time. A successful GIS implementation must be able to make necessary adjustments to the changing technology and organizational needs.

Shih-Lung Shaw

See also Business Models for Geographic Information; Geographic Information Systems; Geoslavery; Geospatial Industry; GIScience; GIS Design; GIS in Archaeology; GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Land Use Management; GIS in Local Government; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; GIS Software; Spatial Data Integration; Spatial Data Models

Further Readings


GIS IN ARCHAEOLOGY

Since its origins in the 19th century, the modern discipline of archaeology has been based on an understanding of spatial phenomena at a range of interconnecting scales. Whether plotting distributions of artifacts and structures across a site or sites within a landscape, spatial relationships have been fundamental to thinking about past human lives and about social structures and relationships. Archaeology has also had a long and fruitful relationship with geography through the exchange of
methods, techniques, and theoretical approaches; and it is not surprising, therefore, that geographic information system (GIS) technology was rapidly adopted by archaeology and has formed the basis of much analysis since the early 1990s.

The use of GIS in archaeology can be broadly divided into the two areas of cultural resource management (CRM) and landscape archaeology. Most countries have national or regional inventories of archaeological and historical sites and monuments often integrated into development legislation and planning control. Traditionally, these records have consisted of information about archaeological sites tied to maps and so are ideally suited to GIS technology. One of the strengths of GIS is the ability to integrate and manage large amounts of diverse data, and that capacity is well demonstrated within CRM, where written information, map data, and various types of images all need to be readily available for a specific place to respond rapidly to a development threat. Another aspect of CRM, one that is particularly important in North America, is the predictive modeling of the location of archaeological sites. GIS is used to analyze the locations of known sites and produce predictive maps that indicate where sites may be found, a procedure of great value when large areas of landscape cannot be surveyed and evaluated through fieldwork. In many countries, the move toward online CRM databases is well under way, enabling easier public access.

Much archaeological work these days is conducted at the landscape scale, and an interest in landscape, often a rather vague and contentious term that can involve a range of different approaches and understandings, is something that unites today’s archaeology and geography. Again, the data sets used here can be large and diverse, consisting of various surveys, including aerial photographic, geophysical, and surface walking and earthwork details, as well as environmental information and targeted excavation. GIS technology is now considered essential to correlate and manage all these georeferenced data together with the attribute data sets that link with them. Archaeology is not just about gathering data, although this is an important aspect of most archaeologists’ work, and many field-based data these days originate as digital information (“born digital”), so inputting it into a GIS is part of the process. Once collected, data have to be analyzed and presented as an interpretation of some aspect of past people’s lives.

The adoption of GIS in archaeology in the early 1990s was not entirely uncontroversial and has generated considerable debate, again similar to that within geography. A popular early use of GIS was to model the “catchment” areas of archaeological sites, using buffering to try and establish their areas of economic control. Another was the modeling of site territories and hierarchies using Thiessen polygons and the principles of central place theory. Although still occasionally used, with some interesting results, these were generally criticized as being environmentally deterministic, and, so it was argued, such models were rooted in a mode of positivist interpretation that underwent severe criticism by the developing postmodernist archaeology of the late 1970s and early 1980s. The response by GIS-using archaeologists was to try and develop approaches that humanized the modeled landscape by attempting to position the analyst within it, the two most popular areas of work being visibility and movement studies.

An essential aspect of both visibility and movement modeling is the use of a digital terrain model (DTM), which is a cell-based representation of altitude and, therefore, a model of the topography. Visibility modeling uses line-of-sight and the more encompassing viewshed to try and establish the visibility characteristics of an area of landscape. Archaeological sites can then be explored to see which are intervisible, which landscape features are visible from particular places within a site, and a whole range of other possible visibility relationships that may help the understanding of how people lived in and used those places in the past. Recent work on visibility has attempted to move beyond the simple binary viewshed (is something in view or not?) to model more subtle understandings of how visibility is affected by distance, direction, and other factors. Similarly with movement, either linear cost paths, from a given start and to a given end point, or a cost surface can help think about how people moved across and accessed various landscapes. The “cost” of moving can be modeled using slope and/or other environmental variables such as ground cover and/or cultural variables such as
not wanting to go near cemeteries or other taboo places. The combination of visibility and movement has gone some way toward enabling the understanding of past landscapes.

At a very different scale, GIS is also now often used for excavation recording, where individual pits, ditches, postholes, and other structures are digitally planned, and the artifacts contained within them are linked through the database. Because GIS is multiscalar, individual site plans can be integrated into wider landscape studies so that a wealth of detail can be accessed at both the landscape and the site scale. Archaeology is a discipline that has the understanding of space at its core, and the tremendous power and flexibility of GIS goes a long way toward meeting its spatial needs.

Gary Lock

See also GIS Implementation; GIS in Environmental Management; GIS in Land Use Management

Further Readings


GIS IN DISASTER RESPONSE

Geographic information system (GIS) technology is used in many phases of disaster management, principally for risk mitigation information and damage assessment, as a tool for supporting decisions during the impending crisis, for sharing information, and as a basis for emergency plans. It should be noted in advance that while rescue, relief, and recovery are aimed at coping with the crisis, reconstruction and preparedness should be devoted to the mitigation of possible future disasters in terms of realization of adequate settlements and community innovations. Currently, the potential, performances, and presence of GIS in all disaster phases are expanding. This has emerged because GIS potential is fostered in combination with ubiquitous information and communication technologies, the increasing availability of geospatial technologies (e.g., the Spatial Video Acquisition Systems, global positioning systems [GPS] incorporated in mobile phones, Google Earth imagery), and the number of hazard data sets. The use of GIS in disaster response is also expanding because of the increasing number of disastrous events and the various sources of such disasters (natural, technological, security) in current societies.

Examples of GIS in Disaster Response Phases

In the first stage of the response phase, GIS can assist decision makers in understanding the scope of the damage; analyze critical infrastructures for health services, food and goods supply, and transportation routes for potential evacuation and operations management; identify suitable locations for rescue officers and civil protection command posts, in case these areas have not yet been identified in emergency territorial plans; identify locations where people may be trapped or require rescue and medical assistance; and identify shelters and possible camps for refugees.

In the recovery phase, GIS can identify locations and best paths for obtaining and delivering supplies, communicate with people to reduce their sense of uncertainty on the condition of their homes and rescued people, and keep participants informed about the status of operations. If the disaster persists, GIS can assess and model the secondary effects of the event to warn people and organize a public safety response. GIS can produce mapping for the media, communicate the extent of damage, and enable field operations for outsiders. GIS can produce maps and documentation for all responsible levels of public safety in both logistical and financial resource support.

During the reconstruction phase, GIS can be used to support decision making and monitor land planning and to redefine hazard zones and distribution of risks both equal and unequal across various residents.
During the preparedness phase, GIS-based applications may include indicators of vulnerability at specific places, early warning systems, and systems to ease emergency response as well as community learning, simulations with citizens to build their awareness, communicating risk and proper behavior, and also receiving data and information from citizens.

In all stages, GIS can help track, assess, and visualize the status of the response and of relief and recovery efforts.

**Criticisms and Further Development**

Although GIS developments in disaster response have been noteworthy, there are weaknesses that ought to be overcome if further development is to follow. Some criticism comes from recent experiences with disaster management in the United States and abroad. It has been noted that during the emergency response phase of rescue and relief, the majority of first responders are not sufficiently familiar with GIS, nor are they likely to use GIS tools in the immediate rescue phases. In this regard, the major criticism of GIS involves the lack of intuitive user interfaces and the need for widespread adoption of GIS among governmental entities to increase awareness and their willingness to adopt GIS tools. A second issue is the need to organize and deliver effective training in GIS use to personnel of government agencies involved in disaster preparedness, response, and management, so that spatial data and their derivatives become a common language for operations. Data quantity, quality, availability, integration, and interoperability are in many instances underdeveloped, thus hampering the effectiveness and increasing the time of the response. Especially for rural areas, some data sets important for disaster response often do not exist. There is an increasing need for integrated spatial data systems linking local georeferenced data with national spatial data and a need to provide updated data on local building inventories, geology, and critical infrastructure as well as better temporal and spatial estimates of tourists, homeless people, undocumented workers, and daytime populations. More research efforts should be invested in integrating physical processes and social models for enhanced predictions of impacts. Another need relates to developing GIS workflows, enabling cooperation among agencies.

Some scholars have investigated the potential for using real-time 3D GIS for the implementation of intelligent emergency response systems to facilitate quick emergency response in multi-level structures (e.g., multistory office buildings). Others have pointed out that the postdisaster recovery phase has received little attention from the GIScience community, partly due to the difficulties in gathering data in a postdisaster environment. The GIScience community has to pay more attention to all scales of rebuilding and their spatial dimensions (individual, community, wider city, and regional scales) within a GIS environment.

Methods should include community-focused information dissemination as well as data archiving for comparative research among events and geospatial technologies, such as capturing GPS-encoded digital video for dynamic collection of recovery indicators, and they should provide mechanisms for spatial data to be shared in publicly accessible formats.

GIS should be used in a participatory fashion: not just communicating risk to a community but also integrating information about hazard and assets from citizens. Information sharing for decision support and risk communication can be enhanced by interactive mapping rather than static Web data portals.

Maria Paradiso

See also Geographic Information Systems; GIS Design; GIS in Environmental Management; Humanistic GIScience; Internet GIS; Natural Hazards and Risk Analysis; Remote Sensing in Disaster Response

**Further Readings**

GIS IN ENVIRONMENTAL MANAGEMENT

Since the early 1970s, geographic information systems (GIS) have been used extensively in environmental management using spatially intensive and extensive databases in an integrated manner. The geographic database includes the collection of samples that are truly representative of any large irregular regions. These samples are turned into useful information to monitor environment that might otherwise be invisible. GIS works on the principle that by bringing together geographic data from different sources and using them in an integrated manner, proper communication among the public and policymakers becomes possible, enabling them to engage in complex environmental decision making. Simply put, GIS bridges the gap between the hard and soft sciences in environmental decision making. It plays a vital role in data validation, digital data transfer standards, and data retrieval, dissemination, and analysis. The evolution of spatial data standards, the Internet, and the next generation of GIS technology will allow all types of users to access environmental information in its proper spatial context in a cost-effective manner. GIS can help deal with location issues and understanding why and how certain things happen at certain locations and how to allocate demand for services.

Though GIS use in environmental management started with the visualization of different layers in the late 1970s, today, it ranges from land surface analysis to emergency services such as forest fire prevention, to hazard mitigation and planning, monitoring air pollution and control, disaster management, precision farming and animal litter applications, human health issues, planning and managing natural resources, and assessing the environmental consequences of economic development. These applications of GIS involve hypothesis testing and geovisualization.

Other applications of GIS in environmental management that are related to land surface and subsurface include terrain modeling, mine exploration, land reclamation, and mapping areas of rehabilitation. Through the overlay of various thematic layers representing spatial distributions of environmental variables and the mathematical modeling changes in these variables, GIS helps in calculating and visualizing the spatial relationships of biophysical factors directly influencing the environment. Factors such as steepness of slopes, aspects, and vegetation density can be viewed and overlaid together to determine various environmental parameters and to conduct impact analyses. The integrated information system used in GIS leads to better decision making within the geographic framework through an understanding of how elements of the environment interact across a landscape. This understanding helps not only to display relationships among key variables but also to test hypotheses concerning, for example, the status of habitats, wetlands, water quality, channel characteristics, adjacent land uses, and natural features in an environment.

GIS applications touch all our daily activities; GIS links environment regulations with human day-to-day activities. Its use to monitor human-environment interactions results in the production of more effective, efficient, equitable, and predictable outcomes. For example, GIS is used in


the analysis of discharge contents of streams and rivers, hazardous substance tracking, landfill sites, waste transfer treatments, disposal sites, and enforcement and prohibition notices brought against organizations as per environment regulations.

In monitoring air and water pollution and in pollution control, disaster management GIS tools can be used in profiling pollution levels using pollution gradient maps. They are used to locate devastation sites and to estimate the amount of devastation. By using GIS, an analyst can rapidly map waste storage sites; describe the volume, content, and state of waste containers; retrieve previous inspection records to compare them with existing environmental conditions; and view environmental data in relation to adjacent geographic features such as waterways, neighborhoods, or other sensitive areas (e.g., high-risk zones for landslides) and in relation to local water pollution levels.

In precision farming, a field crew can use GIS in conjunction with a global positioning system (GPS) to accurately ground truth high-resolution satellite imagery to locate areas that need specific fertilizer applications and areas that need attention in terms of eutrophication. GIS also is useful to locate oil spills, volcanic activities, and their effects on the surrounding ecosystem. Digital information can be overlaid on aerial photographs or satellite images to provide environmental data analysts with familiar views of landscapes to enable them to reach a quick decision.

To monitor environmental problems, the assessment of hazards and risks becomes the foundation for decision making and for mitigation activities. GIS supports activities in environmental assessment, monitoring, and mitigation that can be used for generating environmental models. GIS can be employed to deal with issues of spatial error and uncertainty through the use of statistical modeling, fuzzy sets, and fractal analysis at different scales over time.

In planning and managing natural resources, GIS has been instrumental in inventorying and mapping vegetation across landscapes to better understand the nature of threatened and endangered species for scientific and management purposes. GIS maps are helpful for estimating forestry species stocks, monitoring land clearing, examining farming systems, and estimating carbon sequestered by various plant species. Likewise, GIS helps farmers in performing site-specific spatial analyses of agronomic data, mapping and managing timber resources, and maintaining sustainable forest management. GIS is also useful in land valuation, timber market analysis, harvest route planning, and landscape visualization.

Despite the diverse uses of GIS in environmental management, there are challenges to a more extensive use of GIS technology, especially in Third World countries. Some of the notable problems include nonavailability of high-resolution spatial data; lack of a proper infrastructure, such as a working environment within government bodies; meager-skilled manpower in government planning and development departments; and expensive and unaffordable GIS software and hardware. Nonetheless, GIS technology will continue to play a vital role in environmental system management, and it will likely become the primary information repository, which can be quickly accessed and viewed when required. GIS is becoming more suitable for environmental management requiring real-time display of information. In conclusion, GIS helps rapidly access information for safe, efficient, and sustainable environmental management and decision making.

Keshav Bhattarai

See also Environmental Management; GIS in Disaster Response; GIS in Land Use Management; GIS in Water Management

Further Readings

GIS in Health Research and Health Care

A burgeoning area within the subdiscipline of medical geography, research on geographic information systems (GIS) and health has increased dramatically in recent years. Importantly, the use of GIS in health research has become common in areas outside geography, including public policy, public health, health informatics, and biomathematics, and in medical and nursing schools. GIS techniques are now embedded in health surveillance systems and are used to produce cartographic representations of disease distributions and patterns. In the arena of analysis, pattern and cluster analysis have been the primary techniques employed in most published research in GIS and health. Finally, cutting-edge GIS and health projects are experimenting with participatory GIS methods to improve simulated pandemic responses and early warning systems and to promote the adoption of critical perspectives within work on health and GIS.

Surveillance Systems and Emergency Management

Electronic tracking of infectious disease and environmental public health has become commonplace in much of Western Europe and is increasingly a part of public health practice in the United States. Figure 1 illustrates infectious disease tracking systems before and after electronic documentation was implemented in the state of Florida. Essentially, health workers can now quickly access and analyze spatial information on infectious diseases. With the emergence of health digital surveillance systems, techniques for ethically masking sensitive individual data have been developed, as have mechanisms to communicate spatial distributions of a disease over the Internet. Emergency management systems have also made significant inroads in incorporating GIS in all emergency vehicles. Using GIS for deciding new hospital and clinic locations and assessing accessibility to care is now ubiquitous.

Cartographic Visualization

Some of the earliest work in medical geography has involved mapping diseases and their environmental correlates. Historical and modern atlases facilitate spatial pattern analysis and inquiry. Several federal and state health agencies now provide Internet atlases, a few of which maintain real-time or close to real-time information.

Pattern Analysis

Many innovations in the area of spatial analysis have risen in response to public health challenges, particularly in identifying significant evidence for the spatial clustering of cancer. Several specific GIS applications have been developed for the investigation of pattern analysis in health data, including GeoDa and SaTScan. Such tools help prioritize areas for funding and help direct targeted public health programs. As data specificity has expanded from general regions, such as counties, to exact residences and places of work, a number of simulation techniques, including agent-based modeling, propose to model the human-to-human diffusion of infectious diseases. These simulations suggest strategies for rapid response in the form of selective urban quarantines in the event of a pandemic, such as the highly anticipated influenza pandemic.

Early Warning and Prediction Systems

Several early warning systems predict the diffusion of disease vectors, such as mosquitoes (in
anticipating West Nile virus, dengue fever, and malaria cases) and tsetse flies (in trypanosomiasis cases). These early warning systems rely on GIS and remote sensing to detect changes in the environmental correlates of vector habitats (vegetation, humidity, rainfall, and temperature). For diseases in which the diffusion patterns are less clear, such as meningitis, environmental correlates (such as proxies for the level of dust in the air) are being used to predict outbreaks. Last, although they are more than a decade in the making, early warning systems for famine continue to be developed by integrating spatial population data, information on livelihood zones, and environmental correlates such as rainfall, temperature, and crop yield.

**Adoption of Critical Perspectives in Health and GIS**

Scholars and public health practitioners increasingly choose to adopt public participation GIS techniques to promote community alliances with public health departments, particularly to investigate environmental health and justice concerns. Of specific priority, many GIS and health projects seek to raise awareness of health differences...
across racial and ethnic groups, between men and women, and within countries, states, and cities. Mapping of geographic disparities in life expectancy and quality and access to health care highlights the disadvantage for populations living in the southeastern United States experiencing the highest mortality rates. The geographic disparities are so remarkable that the reduction of such differences has become a stated goal of the federal initiative Healthy People 2010. Travel logs, combined with photographs and narratives, have been mapped as a way to complicate and enrich traditional GIS techniques that seek to understand spatial patterns of inequities in health. GIS assessment of access to not only health care but also healthy food sources, recreation, and green space contributes significantly to research on obesity in urban settings. Health metrics, especially infant mortality and child malnourishment, have been used to critique the strictly economic metrics of development and now appear widely in atlases and development reports.

Lisa Jordan

See also Critical GIS; GIScience; Health and Health Care, Geography of; Medical Geography

Further Readings


Land use refers to the various ways in which land may be employed for human or other activities. Inventoring, classifying, and analyzing land resources and their use have always been important themes in applied geographical research, with significant implications for urban, rural, and regional planning activities. The use of geographic information systems (GIS) and related geospatial technologies in land use management is both well established and diverse, with widespread applications related to agriculture, forestry, wildlife, outdoor recreation, energy development, transportation, and urbanization. GIS applications in land use management vary in terms of function from inventory and mapping to suitability analysis and spatial decision support.

Land Use Inventory and Mapping

The first “named” GIS—the Canada Geographic Information System (CGIS), pioneered by Roger Tomlinson in the mid 1960s—was, in fact, part of the Canada Land Inventory, largely undertaken to address the need for improving national land use policies. In addition to the CGIS, other prominent North American examples of GIS-based inventory and mapping from the 1960s include the Minnesota Land Management Information System and New York’s Land Use and Natural Resources Inventory System. These efforts were all significant in their pioneering use of digital computers to store, manipulate, update, and display geographically referenced land use data and integrate it with other types of similarly mapped environmental and socioeconomic information.

In the 1970s, the U.S. Geological Survey (USGS) undertook a nationwide inventory of land cover and land use for the development of a remote sensing-based series of intermediate-scale map products. To address the data management and analysis challenges of such a large undertaking, the Geographic Information Retrieval and Analysis System (GIRAS) was developed. In addition to producing computerized cartographic output, GIRAS also supported storing and querying...
Hierarchical land use attributes representing multiple levels of mapping detail.

Another, more recent example of a GIS-based land use data inventory was the digitization of soil surveys by the U.S. Department of Agriculture’s Natural Resources Conservation Service (NRCS). Initiated in the early 1990s and designed for use by landowners and local government managers, this effort resulted in highly detailed and richly attributed county SSURGO GIS databases and the more generalized state-level STATSGO products.

Today, GIS-based land use inventory and mapping activities are widespread in state and federal land management agencies as well as local tax assessment departments and planning offices. Combined with land ownership (i.e., cadastral) data, such specialized GIS is sometimes referred to as land resources information systems, or simply land information systems.

**GIS-Based Land Use Suitability Analysis**

Land use suitability analysis involves identifying the most appropriate geographic pattern for future land use activities. Contributing factors may include both the fitness of the land for particular uses as well as the cultural and socioeconomic values and interests of the individuals, groups, and/or organizations involved. GIS-based methods for land use suitability analysis are historically tied to the concept of hand-drawn overlay mapping in landscape architecture, applied first as “sieve mapping” techniques in the late 1800s and early 1900s and advanced with Ian McHarg’s ecological inventory process in the 1960s.
In the 1960s and 1970s, computer-assisted overlay techniques were developed to address the cartographic and data management limitations of manual overlay mapping methods. Many of these advancements were associated with the development of pioneering cartographic modeling software applications by Carl Steinitz and others at Harvard University’s Laboratory for Computer Graphics.

As GIS continued to evolve in the 1980s, the “map algebra” concept formalized by C. Dana Tomlin at Harvard and Yale became the basis for much of the GIS-based land use suitability modeling that continues today. With map algebra, mapped data layers are overlaid or combined in equation-like fashion using operations such as “add,” “subtract,” and “multiply.” Common types of map algebra overlays include union operations—where conditions for only one input datum must be met; intersection operations—where conditions for all input data layers must be met; and weighted linear combination functions—where weights of relative importance are assigned to various input data layers and then combined to generate an overall suitability score layer output.

To address concerns with standard map algebra methods such as WLC and to better incorporate stakeholder value judgments in decision processes, multiple-criteria decision-making (MCDM) methods have increasingly been integrated with GIS-based land use management analysis and decision making. Additional spatial decision support approaches may be categorized as indicator-based scenario evaluations or as artificial intelligence methods, including fuzzy logic techniques, neural networks, genetic algorithms, and cellular automata and related agent-based methods.

Spatial Decision Support

In general, spatial decisions are those in which geographic conditions either influence, or are influenced by, the decisions being made. Spatial decisions are inherent in management of land use. As GIS became more directly accessible to planners, managers, and decision makers in the 1990s, the technology and its associated geographic methods were more widely applied to support spatial decision-making activities, including those involving land use. The most common approach has been the weighted linear combination (WLC) method of combining (i.e., overlaying) multiple thematic decision factor data layers to identify suitable or unsuitable locations for future land use allocations. While relatively easy to parameterize and generate results, WLC methods have been criticized for not addressing the assumptions inherent in weighting procedures and the potential interdependency among input factors, often oversimplifying solutions for complex situations.

Jeffrey D. Hamerlinck

Challenging land use management issues continue to foster further advancements of GIS technology and its application, especially in the areas of data development and software accessibility. For example, land use inventories are improving in terms of completeness, accuracy, and timeliness as a result of more standardized and higher-resolution remote sensing programs and platforms. Furthermore, the evolution of Web-based GIS has both increased the accessibility and use of data and provided for wider public participation in land use decision-making processes.

Other Applications and Future Prospects

See also GIS in Environmental Management; GIS in Urban Planning; GIS in Water Management; Land Use Analysis; Land Use and Land Cover Mapping; Remote Sensing; Resource Mapping; Spatial Decision Support Systems

Further Readings


GIS IN LOCAL GOVERNMENT

Geographic information system (GIS) technology in local government has been implemented to support many government functions, and its use is expanding every day. GIS implementation at the local level depends on several factors. These factors and functions are described in more detail below.

Distributed Versus Centralized Environments

A local government GIS may be implemented in either a distributed or a centralized environment. In the distributed environment, GIS exist in different departments, each of which provides tools and analysis for their own use. In the distributed environment, practitioners may share all, some, or none of their data between departments. In the centralized environment, most spatial data are provided on a common platform for storage and dissemination that adheres to standards set by the jurisdiction. A centralized environment accommodates the workflows of multiple departments, establishes responsibilities for individual data themes, and avoids the duplication of efforts by separate departments with the trade-off being the cost of compromise in the development of a standardized data frame and the loss of individual control over data. Although a local government may have a centralized implementation of GIS, it does not always mean that all spatial data are stored in a central repository. There may be issues associated with certain data themes that prevent them from being stored with the jurisdiction’s centralized data. Examples are data pertaining directly to law enforcement, health and human services, or homeland security.

Department Location and Staff

GIS may fall under the purview of the information technology department, may be an independent department, or may exist under another department, such as Planning or Public Works. GIS is data and technology resource intensive, use a variety of software, and contain applications for internal and external (public) use. Each jurisdiction must examine its needs and organizational capacity to best locate the management of their GIS.

GIS implementation at the local level often depends on the size of the jurisdiction. Large jurisdictions typically have a more centralized system with support from programmers, IT staff, and administrators. In small jurisdictions, the GIS staff is usually composed of one or two people who perform all functions in support of their GIS instance.

GIS Functions and Applications at the Local Level

GIS in local government supports many different governmental functions.

Public Facility and Infrastructure Management

In 1999, the Government Accounting Standards Board made changes to the way infrastructure must be tracked and accounted for. This standard is commonly referred to as GASB34. As a result, many local governments moved to asset management systems that interface with GIS, to create a current inventory of assets and their locations. Integrating asset management with GIS has given governments the ability to more efficiently manage their work orders, assess areas for capital improvements, track infrastructure conditions, assist with budget projections, and
improve customer service through online mapping applications.

**Planning and Zoning**

The maps and associated data are used visually or through models to assess current and future needs. Frequently, this information is then used in GIS-based transportation models to assess what transportation infrastructure might be needed to support land use changes. Some governments have made this information available through online mapping applications that citizens can use to identify the zoning regulations for specific properties or that businesses can use to site new locations. In addition, GIS is used to track building permits and business licenses so that planners can assess the types of activities that are taking place in various neighborhoods.

**Emergency Services and Law Enforcement**

Computer-aided dispatch (CAD) systems use GIS to route personnel to incident locations. GIS analysis is used to identify what fire stations would most appropriately serve individual properties and what infrastructure, facilities, or hazardous materials are within the vicinity of an incident. Evacuation routes can be generated through GIS. Law enforcement analysts use GIS to look at overall or specific crime trends, track individual criminals, and analyze the effects of streetlights or the local economy on neighborhood crime. During an incident, GIS is used to generate data and maps for decision makers and the media.

**Environmental Management**

Parks and recreation departments use GIS to identify the locations of parks, what functions they support, and specific maintenance requirements. GIS is also used to track agriculture and the types of crops that are grown, pests and pesticide management, water use and runoff, habitat management and mitigation, invasive weed locations and abatement, and air quality and to analyze energy use and potential solar radiation or wind production within the jurisdiction.

**Health and Human Services**

Health and Human Services (HHS) personnel use GIS to identify special needs and care facilities, hospitals, and clinics and to track disease outbreaks. Some local governments have GIS-based self-registration Web sites that allow individuals with special needs to identify themselves and what services they might need, such as power during an emergency or assistance required for evacuation.

**Public Information and Education**

Many local governments have set up online mapping applications that provide a visual tool that allows the viewer to see not just a location on a map but also information associated with that item or location. More and more local governments are opening their GIS to allow public input. Local governments are creating applications that ask the public to input the location of items of interest, such as city trees, streetlights, potholes, or storm drains. Some local governments have made the results of urban planning or habitat models available for public comment; others have made models within their applications that allow the citizens to alter model parameters and offer their own interpretations of what is needed in their community. Such interactive GIS applications can lead to a better-educated public, who more fully understand the parameters and the trade-offs that are part of the policy decisions under consideration.

No matter how implemented, the adoption of GIS has allowed local governments to improve their workflows, better track their assets and work orders, enhance public health and safety, and enhance their understanding of their decisions on the surrounding environment.

*Paul E. Hardwick*

See also GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; Spatial Decision Support Systems
Since the late 1980s, geographic information systems, or GIS, have become almost ubiquitous in public organizations and throughout the nonprofit sector. Over this period, geospatial capability has become essential. The powers of GIS, including the assimilation, analysis, and graphical display of large volumes of geographically coded (geocoded) information, are widely recognized. They are typically used for purposes such as managing planning and zoning, geodemographic service management, emergency response system optimization and path selection, targeted-facilities location, and many others. Much of the innovation has been driven by the use of GIS for private sector marketing and spillover functionality that public organizations have capitalized on. At the same time, some functional areas, such as more reflexive data capture for GIS using Internet applications, are being targeted by both academic researchers and public sector developers and practitioners.

But why does—or should—GIS matter for public policy? Normatively, this entry assumes that the purpose of GIS in public policy is to increase spatial justice, that is, the distribution of costs and benefits across regions, areas, and populations. This justification is often presented by public organizations charged with improving the quality of public goods allocation. As Paul Longley (2005) argues,

In policy terms, these developments [widespread adoption and use of GIS by governing institutions] also arise out of greater recognition of the importance of preventative communications programmes (e.g., in health and policing) and the opportunity to improve efficiency by targeting them to those most at risk. (p. 59)

This entry presents a brief overview of significant trends within GIS literature in geography, planning, and critical GIScience literature and connects these with the public policy field. The range of public policy applications considered includes policy, environmental management, transportation and land use planning, and infrastructure design. Rather than presenting a laundry list of citations and examples of technical applications, this entry highlights several current trends in the deployment of GIS for public policy, to illustrate some technical developments that promise to increase functionality and to outline some structural impediments to the achievement of better spatial justice in public policy application.

### Overview

A deep-rooted but rather thinly supported and almost ideological set of assumptions governing the utility and value for money of GIS generates significant enthusiasm among policymakers and government officials. Almost all the claims advanced in relation to public policy applications of GIS have focused on its potential to “improve” collaborative decision making in some way or another, either by including more stakeholder valuations and more data or by analyzing them in more effective ways, or both. Other advantages include supporting decision making and improving communication and collaboration. Improved spatial justice is imputed from this performance. The practical justifications offered by software vendors focus on efficiency. For example, the GIS developer and vendor ESRI (Environmental Systems Research Institute) lists 10 advantages of GIS for state and local governments, 5 of which involve revenue maximization or cost avoidance. Similar claims have been made by IT vendors with respect to their products for more
than 30 years. In this regard, as with most IT domains, even the more limited efficiency claims advanced by software vendors are hard to quantify because focused life cycle benefit-cost analysis does not exist. Indeed, in a 2002 survey of the public sector GIS user base, Gregg Kreizman found that 37% of respondents stated, “No financial analysis is used to justify GIS implementation.”

Nevertheless, a rather technotopian view of “efficiencies” associated with GIS adoption has acquired currency, at least among many public officials and organizations. These enthusiasms are evident in the wide-ranging presentation of GIS applications at conferences such as those of the URISA and ESRI. The size of this sector is clear from the magnitude of the annual ESRI User Conference, which is one of the world’s largest professional GIS gatherings: In 2008, it hosted 14,500 attendees. In the higher-education sector, GIS certificate programs have proliferated in response to the market developed by working professionals who wish to upgrade their skills and secure geospatial certification. Many participants are working in fields related to public policy. Undergraduate class offerings have expanded similarly, and in fields such as urban growth modeling and environmental management, there is a consciousness among students that a GIS credential is a strong asset in the job market.

Trends

Examining the broad sweep of the GIS field, three trends are evident. The first is the apparent democratization of GIS technology. In geography, researchers have coined terminology such as public participation GIS (PPGIS) or participatory geographic information science (PGIS). Methodologically, this democratization takes the form of efforts to allow more decentralized data definition, capture, and input to GIS databases, for example, to encourage recreational users and stakeholders to define their areas and types of use with the intent of developing more inclusive and reflexive management policies for common resources such as national parks. This involves researching improvements in the way geospatial data are thought of and handled. These projects have sometimes entailed community factions at loggerheads with public offices, and there is little doubt that these uses of GIS have modified the way in which public policy is developed and managed using GIS.

A second significant trend is the convergence of geospatial technology with (geo)visualization, particularly real-time visualization and virtual reality display modes. GIS vendors compete to add real-time visualization capacities to their platforms and to facilitate interoperability with high-end rendering and graphical packages, allowing pseudorealistic visualization of urban environments with geocoded data such as parcel boundaries and locations. CommunityViz and WhatIF? seek to increase analytic functionality. At the local or urban scale, planning support systems are one of the most high-profile types of GIS application to public policy.

A third trend is improved accessibility with respect to geospatial information, both upstream and downstream. This accessibility enhancement is conceived in physical terms such as miniaturization and overhead reduction; palmtop devices and mini laptops, without full functionality, have spurred the development of software such as ArcPad, allowing a subset of GIS operations to be performed on the road. Accessibility is also enhanced through new media dissemination systems, such as integrated Web delivery of geospatial and visualization data, permitted by increasingly interoperable GIS/database and visualization software. Nevertheless, Web functionality is still extremely limited. For example, although GIS output is displayed in real time on MapQuest in response to user queries, the capture, geocoding, and upload of spatial information from users are still not feasible without specialized equipment. Once their GIS divisions exceed a certain size, authorities in any case tend to develop and maintain proprietary geospatial databases.

Applications and Impact of GIS in Public Policy

Despite efforts to reduce their resource overhead, GIS platforms remain rather cumbersome and inaccessible. As Peter Kwaku Kyem (2004) notes,
Short of a conscious effort to ensure equal participation, those participants who have prior knowledge of the conflict situation, those with some experience of spatial data analysis, or those close to positions of power would dominate the discussion and alter the results. (p. 52)

This situation is worse in larger-scale public policy questions, where the networks of control are more complex and diffuse and the objectives of GIS deployment vary between stakeholders. As the scale and social complexity of the problem domain increase, public policy applications of GIS become less successful. Even at the urban scale, problems exist. Raul Lejano, for example, argues that GIS use in local planning “increases alienation.” Compared with PPGIS applications, which typically are organically driven by local neighborhood participants and groups to address their concerns and which operate at relatively small spatial scales, the structural problems of power are, if anything, exacerbated by GIS in public policy applications. These problems involve multiple actors.

The impact of GIS on public policy has been clearest in public service delivery involving clearly focused public goods applications such as epidemiology or emergency service provision. This is accounted for by the knowledge structure within which these are used: Technical experts and GIS analysts play a significant role in deciding how to define and harvest information and then to geocode and analyze it. Performance criteria in these focused applications are clearly defined: to minimize the response time of environmental management systems (EMS), for example, subject to certain system constraints.

In the mid 1990s, a strongly critical current of thought emerged among geographers and others concerned with the uncritical and sometimes exuberant application of GIS to social, environmental, and economic problems. In public policy, if not in marketing and private sector applications, it might appear that the systems’ potential as a panopticonic technology is checked to some degree by various laws and requirements that constrain the offices and departments that use GIS. But the social reflexivity with which the systems are deployed is typically limited. For example, although GIS may be used for the management of large-scale public lands by federal bureaus, it is not clear how stakeholder knowledge is incorporated into the decision system. And not all public policy and planning uses of GIS to increase transparency are welcomed by community members. Residents in one local community, for example, were shocked to discover that the local county assessor’s office had, in the process of GIS and property assessment database integration, offered online access not only to the purchase price of their houses but also to their purchase deposit percentages.

Moreover, GIS can only influence public policy to the extent that political ideology permits. The predilections of system managers may, or may not, accord with the stated goals of the offices within which they work. Even with the best will, making the rather exclusive and cumbersome GIS software more socially responsive is not an easy task. Large volumes of data are stored on secure servers, and the actual functionality of the system is managed by departments within local government.

In one example, a large-scale highway-routing project, an analytic method for integrating disparate social, environmental, and human factors into a participatory geospatial decision platform based on ArcView was developed. Having run the model and analyzed the output, the responsible officials were concerned that the routings did not accord with their notions of where the line should be. The lowest net social cost corridors proposed by the GIS-based multicriteria model were considered inappropriate, and the recommendations were not implemented; and the original analytical team moved to other projects. After some years of fits and starts, with various phases of decision making, opposition, resistance, and realignment, the actual routing of this project followed closely the original solution corridors proposed by the model. Given that the original decision criterion was that the system was designed to minimize net social impedance by integrating a broad range of decision criteria generated by a range of stakeholders, this is not surprising.

In the past few years, geographers have applied postructuralist Foucauldian and Latourian analyses of the nature of power in complex, multi-stakeholder systems. The advantages of this
approach include a more nuanced and complex notion of how power flows and how GIS and geovisual technologies fit within this power structure as active agents. This allows researchers to understand more clearly the barriers to implementation in a more geopolitical context and therefore gives insight into how and why GIS fails to realize its potential in terms of increasing stakeholder input quality. These analyses help clarify the differentials between the stated spatial justice improvement objectives and the mundane nature and contingency of organizational practices that, often, confound the will of participants and sponsors. Unfortunately, without large-scale and meaningful GIS applications in the field of public policy to refer to, it is hard for academics to legitimate these critical analyses in ways that work to improve policy over the medium term.

It is not necessary to be a formal technoskeptic, as perhaps some critical GIS and society theorists have appeared to be, to be wary of, and unconvinced by, some of the more optimistic assertions. Nor is it necessary to be such a technoskeptic to know that the core premise of improved spatial justice cannot be assessed readily because the indicators of performance such as “improved collaboration” or “better stakeholder understanding” are not even defined, much less measured and published. In this respect, some argue that the rather utopian promise of GIS, like that of much technology, remains at best largely unrealized and at worst is being undermined by the deployment of these systems within anti- or nondemocratic and non-transparent power structures. For critical theorists of GIS in public policy, seeking to improve the quality of public participation, and ultimately the justice, sustainability, and durability of collaborative decision making, the way forward may include a closer coupling of theories of power with geospatial analyses. It is important to understand how uncritical notions of democracy, consensus, fairness, and justice erode, or even confound, the promise of increased transparency, inclusion, and equity that technoskeptic advocates believe GIS holds. Beyond learning from this work, it is even more critical for geographers, planners, and other critical theorists of GIS to find ways to influence GIS and public policy in the interests of spatial justice by establishing a meaningful dialogue with those who deploy the systems in daily use.

Keiron Bailey

See also GIS in Disaster Response; GIS in Health Research and Health Care; GIS in Local Government; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; Public Participation GIS; Spatial Decision Support Systems

Further Readings


GIS IN TRANSPORTATION

Geographic information system (GIS) technology is often used in improving transportation. Transportation applications of GIS, also referred to as GIS-T, are popular and extensive in scope. Transportation problems range from day-to-day operations (in-vehicle global positioning system [GPS] navigation, the North American E-911 emergency response system) to large-scale efforts (prioritizing policy alternatives, long-range transportation planning) by metropolitan planning organizations. This entry reviews the policy contexts and market forces that influence the way institutions approach transportation problems. Then, data models and operations (with a focus on analysis and modeling) unique to GIS-T are reviewed.

Policy-wise, the span of policy goals has stretched from improving efficiency and mobility (e.g., the interstate highways) to embracing sustainable development, including mitigating negative externalities (e.g., air pollution, safety, congestion), as indicated in the passage of legislation such as the Clean Air Act, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and the Transportation Equity Act for the 21st Century (TEA-21). Along with the changing policy context (as well as advances in geotechnology), GIS-T in the public sector has widened from the inventory of infrastructure and travel demand forecasting to Web-based public participation tools and decision support systems.

Market forces driven by advances in technology (e.g., the Internet, positioning technology, wireless sensor networks) are reshaping the way GIS handles transportation problems. They not only change the way geographic information is serviced, or disseminated, but also change the way geospatial data are captured. The era of what some call geonomadism or geosurveillance has already arrived. GIS-T in the private sector encompasses location analysis, logistics, and location-based services.

To understand how GIS in transportation works, it is necessary to have a grasp of basic data models and operations in GIS-T. Data models and operations are dependent on application needs, and they are interrelated. For example, spatial mapping of the fixed transportation infrastructure, monitoring the pavement conditions of sections of highway, and finding the best route for ambulance dispatch require different specifications of data models and operations.
necessarily begin or end at the node. GIS has capabilities to dynamically generate those events tied to links based on their attributes (dynamic segmentation). Origin-destination matrices are used to store spatial interaction data (e.g., traffic flows among traffic analysis zones), although this is not well supported in generic GIS software due to the dominance of relational databases.

As more GIS-T applications are geared to servicing geographic information in the distributed environment (e.g., location-based services and intelligent transportation systems [ITS], such as the provision of real-time travel information in vehicles, the navigation of vehicles, and automated piloting), further requirements of GIS-T data models are being added. For example, high-resolution (e.g., lane based), dynamic (e.g., moving objects), and multidimensional (e.g., 3D) representations have been proposed. This trend poses challenges in managing, exchanging, and integrating geospatial data of disparate sources. For example, data stored in different location reference systems should become compatible. Strategies for promoting interoperability are being proposed.

Shortest-path problems are at the core of many GIS-T operations. The generic shortest-path algorithm is used in developing least-cost routes for deliveries (the traveling salesman problem) and determining optimal facility locations given the configuration of demand and facility (location-allocation). For example, planners may be interested in maximizing the coverage of health care clinics to the general public and minimizing the distance to demand in deploying ambulances.

Accessibility, as a core concept of transportation, has been a mainstay of geographers’ contribution to this multidisciplinary field. Accessibility can be measured in several ways in GIS. These range from simple buffering (e.g., the number of facilities that can be reached from origins within a certain distance) to spatial interaction models that predict aggregate flows (or the potential of spatial interaction) among zones. Recently, much effort has been devoted to measuring individual space-time accessibility (based on Hägerstrand’s time-geography) in GIS. GPS-enabled travel diary data collection would render this approach more practical.

GIS is used in the four-step urban transportation modeling system (UTMS) universally employed in transportation planning agencies. UTMS that aims at forecasting travel demand consists of trip generation (where trips come from), trip distribution (where trips go), modal split (which modes to take), and traffic assignment (the routes to be taken). The functionality of UTMS is provided in specialized GIS-T packages such as Caliper’s TransCAD. GIS can improve the UTMS features that have been criticized for empirical inconsistency through including better land use modeling as input, visualization for alternative analysis as output, and refining the modeling procedures of the four steps.

GIS-T data can be obtained from the Census Bureau’s TIGER files, the Department of Transportation, GIS software vendors, and specialized data vendors such as NAVTEQ and Tele Atlas. The Network Analysis functionality is provided in ESRI’s (Environmental Systems Research Institute) ArcInfo Workstation and Network Analyst, an extension of ArcGIS and ArcView 3.x, while users can customize functionality using macro-language or componentware.

Sungsoon Hwang

See also Accessibility; Commuting; GIS in Urban Planning; Global Positioning System; Gravity Model; Location-Allocation Modeling; Location-Based Services; Spatial Interaction Models; Transportation Geography

Further Readings


Urban planning is greatly enhanced by the use of modern technology such as geographic information systems (GIS), which are uniquely suited to capture the many spatial layers and dimensions of the contemporary city and provide analytical tools to model its growth and change. Cities, counties, regional planning agencies, and other planning units frequently undertake what-if analysis and problem solving with GIS. GIS are a helpful tool for urban planners because it not only goes beyond just forecasting the magnitude of a problem but also visually displays the spatial distribution of the phenomena being examined.

GIS has been especially popular for smart growth initiatives, sometimes called new urbanism or neo-traditional planning, which encourage compact development with mixed uses, redevelopment of infill areas, pedestrian-friendly walkways, public transportation, open space connecting neighborhoods, and architectural designs that encourage social interaction. The principles of smart growth are articulated with terms such as compactness, connectedness, and interaction, which are all spatial terms, and therefore, GIS becomes the natural tool for implementing such plans.

Consider the contrasting example of what-if planning applied to population growth impacts in an urban fringe watershed west of Chicago (Figure 1, next page). The urban fringe of Chicago has been affected by many negative consequences of sprawl due to rapid population growth. The Chicago Metropolitan Agency for Planning (CMAP) has developed GIS data sets and tools to cope with the impacts of this growth on metropolitan Chicago’s environment, land use, and economic development. Inputs from federal, state, and local planning agencies included cadastral land parcels, land use, extent of prime agricultural land, and open space. In the watershed example, assumptions were entered into the GIS about how growth would occur in the future. For instance, assumptions were made about the nature and policies of land use and whether new development should be kept compact or allowed to be scattered throughout the watershed.

In the first scenario, the GIS assumed no land use controls, and the growth continued to occur in a scattered fashion. In the smart growth scenario, the growth was made compact and took place adjacent to existing development, particularly filling in many bypassed sites from an earlier development period and protecting prime farmland and other green areas. Similarly, the CMAP has undertaken a more comprehensive study of available infill areas throughout the entire Chicago metropolitan area and has held community meetings encouraging a participatory planning process aided by GIS.

Urban planning researchers often apply more complex GIS modeling and simulations referred to as cellular automata. Cellular automata models in a GIS are designed as a grid of cells where the state of each cell depends on the previous state of the cells within a neighborhood according to a set of transition rules. For instance, Jose Barredo and Luca Demicheli, working with the European Commission’s MOLAND (Monitoring Land Cover/Use Dynamics) project, developed a large-scale cellular automata urban growth model for the megacity of Lagos, Nigeria. The city was divided into grid cells of 100 m (meters) by 100 m, with particularly strong land use factors that could be calibrated through the use of time series data. As a developing-world megacity, Lagos experienced very rapid growth in its population and land extent from 1962 to 2000. The model was run, and the city’s urban spatial distribution was projected for 20 years, from 2000 to 2020. It projected that Lagos in 2020 would become a megacity with 27 million persons, encompassing an area of 969 square kilometers, which is more compact than Mexico City today. The model projected rapid growth of the urban area, although with considerable consolidation and infill. The model demonstrated the need for better infrastructure to provide the key needs of water, energy, and communications.

In short, all aspects of GIS have been applied in the field of urban planning, ranging from its use in the inventory of essential planning map layers all the way to sophisticated simulation models of urban development.

Richard P. Greene

See also GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Public Policy; GIS in Transportation; GIS in Utilities; GIS in Water
Figure 1  Urban growth scenarios for the Blackberry watershed up to the year 2020: (A) sprawl growth, (B) compact growth

A utility is a private company, a public agency, or a cooperative of organizations that provide a service to the public. Some services commonly thought of as utilities are electricity generation and distribution, oil and natural gas distribution, telephone and other communication services, cable television, and water and wastewater management. More recently, high-speed Internet services and cell phone provision have become increasingly important utilities. Geographic information systems (GIS) are one of the most important technologies for the efficient operation and management of utilities.

Utility Networks Modeled in GIS

One of the primary reasons why GIS has been thoroughly integrated into utility operations is the development of vector and network data models within GIS. Topological data models were a revolutionary component of GIS, and many of the most common utilities are structured as networks, comprising of topologically connected sets of edges and junctions. As an example, natural gas transmission systems largely consist of sets of connected pipes, where the connections occur at points where the gas is either split from one pipe to many or collected from many pipes into one. At any point along the network, there may be junctions that contain valves, pressure gauges, compressors, or storage facilities. Of course, there must be a production facility (or facilities) and distribution points (homes or businesses) that act as sources and sinks in the gas distribution network. Each of these network elements may have many different attribute values. In the case of the pipes that compose a gas transmission network, attributes include the pipe diameter, its capacity for flow, the date of its last inspection, and perhaps hundreds of other attributes. Similar network structures exist for most of the other utilities mentioned above. The well-developed topological and network data structures that have been integrated into GIS, the network analytical capabilities that are continually being developed, and the underlying relational database management system have combined to make GIS an essential element of utility operations.

Advantages of GIS for Utility Management and Operations

Beyond the clear correspondence between fundamental GIS data structures and utility network systems, GIS holds several other advantages for utility management and operations. Perhaps most important among these is the ability to analyze systems at a wide range of geographic scales. Utilities operate at local or metropolitan (e.g., water and sewer systems), regional (e.g., cable television providers), national (e.g., some telephone systems), international (e.g., natural gas and oil pipeline systems), and even intercontinental (e.g., undersea cable and pipeline systems) scales. At a microscale, GIS can assist with operations within single facilities, and at a macroscale, GIS can assist in global resource planning. The flexibility of a GIS to operate at all these scales allows utility operations to employ spatial technologies throughout their enterprise.

A second advantage of GIS for utility management is the close correlation between traditional GIS data layers and the data needs of utilities. Utilities manage both their own landholdings and the locations of their customers through the use of GIS.
of cadastral databases. They manage regulatory reporting in part through the use of administrative boundaries (e.g., city, county, state, national). They target markets through the use of both census data and ZIP codes. They plan access to their facilities through the use of street centerlines, and they manage environmental impacts in part through the use of hydrographic, topographic, and land cover data sets. Orthophotography is used increasingly in the planning of new utility construction or expansion.

The ability to integrate GIS with other business systems is a key factor in the wide acceptance of GIS in these industries. Address-geocoding functionality in GIS allows utilities to respond to customer needs for service, particularly in emergency situations, when access to services can literally be a matter of life and death. The network analytic functions built into the GIS can assist in the dispatching of emergency crews in the most efficient manner possible. More routine operations such as meter reading or inspection of facilities are enhanced by the ability to use GIS in the field with handheld user interface devices. The ability to integrate database systems allows for diverse activities such as bill and payment processing, asset and equipment management, and engineering planning through integration with computer-aided design systems.

While even routine GIS techniques such as editing, metadata creation, and cartographic production are essential for many utility operations, more advanced GIS technologies hold great promise for these organizations. Three-dimensional (3D) analysis can assist in the modeling and analysis of systems that exist not only on the surface of the Earth but also above it (e.g., raised wires) and below it (e.g., underground pipelines). The process of linear referencing can be used to go beyond traditional coordinate location to identify measure locations along a network and permit the network to be the spatial platform for analysis. The advances in network analysis in GIS, including finding multiple routing solutions and determining flow patterns through networks, bring the field of operations research into utility management.

Since utilities have such a diverse range of activities across the enterprise, since their systems are extremely capital intensive, and since their operations are so vital to society in many ways, the use of GIS to improve operations and more efficiently provide service is a vital contribution. To the extent that GIS can reduce the cost of operations, improve customer service, and help make wise, safe, and secure operational decisions, it will help in reaching a suite of both financial and social goals.

**Kevin M. Curtin**

**Further Readings**


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**GIS IN WATER MANAGEMENT**

Water is an essential resource for sustaining life and the economy, but water resources are scarce. Virtually all human uses of water require freshwater. However, of all water on Earth, 96.7% is saltwater, while over two thirds of freshwater is frozen in the glaciers of Antarctica and Greenland. Thus, we are left with only 0.9% of the globe’s water for our use. This fact, combined with the needs of the growing population, obliges efficient management of water resources. Well-organized water management systems may help people use the limited water resources wisely. Applying geographic information systems (GIS) in water management greatly improves its effectiveness. To facilitate water management, many
hydrologically oriented pieces of software have been developed. Together with an abundance of spatial data generated specifically for hydrologic analyses, such software offers the necessary environment for using GIS in water management.

The management of water resources involves the design, implementation, and development of an organizational, technical, and legal structure for optimizing the exploitation, protection, and monitoring of water systems. Water management tasks range from preserving water for environmental protection and irrigation, to maintaining sewage systems in towns, to the supervision of international water resources on the surface (rivers, lakes, and wetlands) as well as underground (aquifers). Some highly complex water resources are managed under defined local regulations and/or international treaties. The World Bank projects that by 2030, 3 billion people will be living under conditions of severe water shortage. Countries receiving their water supply from across national boundary waters with limited availability experience increasing tension over water rights. Such stress over scarce water resources creates the risk of conflict.

Water management practices may be organized into the following major categories:

- Water treatment for drinking water and wastewater
- Water resources for agricultural, industrial, transportation, domestic, environmental, and recreational purposes
- Flood protection practices along rivers exhibiting flood dangers caused by sustained rainfall or rapid snowmelt and along seacoasts exhibiting flood dangers caused by severe sea storms, tsunamis, or hurricanes
- Irrigation for assisting the growing of crops in dry areas and in periods of rainfall shortfalls
- Groundwater, aquifers, and water tables

In all the above categories of water management, GIS is applied. Management of water resources and flood protection are the two main areas where GIS has been used for many years. For hydrologic analyses, GIS is an essential and indispensable tool.

GIS facilitates the ability to store, retrieve, process, and display spatial data, including data related to surface and groundwater resources and water utilities. GIS-based watershed resource inventories provide information about elevation, slope, topography, soil properties, geology, land cover, flood zones, water reservoirs and their capacity, water quality, precipitation and other relevant climate variables, and demographic and socioeconomic issues. Data management of any watershed would not be feasible without a well-designed database, which is provided by GIS.

GIS is critically important when the spatial dimension of phenomena and their dynamic changes need to be modeled. GIS technology can help with finding spatial relationships in complex systems, with locating problems, and with planning alternative solutions using a variety of means, including simulations. With this, GIS provides a framework for a computer-based water management system that can be effectively applied to both large and small scales.

During the 1990s, GIS emerged as a major support tool for hydrologic analysis and modeling. For instance, GIS provided a reliable method for watershed and stream network delineation based solely on the information derived from a digital elevation model (DEM). Many GIS software vendors offered specialized tools for preprocessing the DEM required for more advanced hydrologic analysis (e.g., filling so-called sinks in the DEM to ensure continuous flow within a stream network, calculating the flow direction at every cell, and providing a foundation for deriving a stream network from creating a flow accumulation raster). These resulted in the creation of a community of GIS-based hydrologic modeling specialists who keep developing both increasingly accurate primary and collateral input data, which are critically important components of GIS in water management, and the know-how for more sophisticated hydrologic analysis and modeling.

To provide high-quality standards for the data and to facilitate water management applications, the U.S. Geological Survey (USGS) has developed a hydrologically correct National Elevation Dataset and National Hydrography Dataset of various fine resolutions for the territory of the United States. For the entire globe, the HYDR01K data (also developed by USGS) consists of a DEM
with 1-km (kilometer) resolution preprocessed for hydrologic analysis. HYDR01K provides a suite of georeferenced data sets, both raster and vector.

In the United States, various thematic GIS data layers are available online in open-access mode. The National Spatial Data Infrastructure focuses on the distribution and access of geospatial data, encourages spatial data sharing, avoids costly duplication of data sets, and directs all federal agencies to work cooperatively with other sectors to ensure the infrastructure’s growth and evolution.

The development of data and the proficiency of hydrologic analyses have stimulated the GIS industry to further extend their software. This new “generation” of software enables progressively advanced GIS-based analyses, which by the end of the 20th century became the core of water management. With this, many companies have developed GIS packages for sophisticated hydrologic analysis and simulations that are essential for water management, including the evaluation of alternative water management options. Some of these, such as HEC-1, HEC-RAS, HEC-HMS, StormDrain, GSSHA, TR-20, TR-55, NFF, Rational Method, HSPF, DAMBREAK, MODFLOW, EMS-i, and MIKE21, were developed on top of the basic functionality of larger, generic packages of GIS, such as ArcGIS. Others, such as the HSPF, MT3DMS, MIDUSS, SWMM, XPSWMM, and QHM, are stand-alone pieces of hydrologically oriented software.

There is no alternative to the application of GIS in water management and in water-related information and decision support systems. The growth of GIS, together with the development of data and the continuous advancement of techniques for hydrologic analysis, offers an important resource for those involved in water management to meet global water needs.

Witold Fraczek

See also Floods; Hydrology; International Watershed Management; Public Water Services; Surface Water; Urban Storm Water Management; Urban Water Supply; Wastewater Management; Water Management and Treatment; Water Needs; Watershed Management; Watershed Yield; Water Supply Siting and Management

Further Readings


GIS Software Concepts

Software that is used to create, manage, analyze, and visualize geographic data, that is, data with a reference to a place on Earth, is usually denoted by the umbrella term *geographic information system (GIS) software*. Typical applications for GIS software include the evaluation of places for the location of new stores; the management of power and gas lines; the creation of maps; the analysis of past crimes for crime prevention; route calculations for transport tasks; the management of forests, parks, and infrastructure such as roads and waterways; and applications in risk analysis of natural hazards and emergency planning and response. For this multitude of applications, different types of GIS functions are required, and different categories of GIS software exist that provide a particular set of functions needed to fulfill certain data management tasks. This entry first explains important GIS software concepts; then it lists the typical tasks accomplished with GIS software and describes different GIS software categories; finally, it provides information on software producers and projects.

To represent a geographic object in a GIS, for example, a building or a tree or a forest, a data representation has to be established first. GIS usually provides two different possibilities to represent a geographic phenomenon: the raster representation and the vector representation. In the raster
In GIS software, geographic objects that have the same geometric and attribute representation are typically grouped in so-called layers to simplify data management tasks. For instance, all buildings that are represented by polygons and have information on owner and construction year are grouped in a layer labeled “buildings.” Figure 1 shows the typical graphical user interface of a GIS software package that includes the concept of geometries (map view) connected to values in tables (attribute view), as well as layers that contain one class of objects (e.g., rivers).

**Figure 1**  A typical desktop GIS user interface with map view, layer view, attribute view, and tools for navigating and exploring data, as well as tools for creating and modifying geometries

*Source: Stefan Steiniger.*
providers. Hence, data need to be created and—in case something has changed—edited and then stored. If data are obtained from other sources, they need to be viewed and eventually integrated (conflation) with existing data. To answer particular questions—for example, Who is living at Address X and is going to be affected by the planned renewal of a power line?—the data are queried and analyzed. However, some specific analysis tasks may require data transformation and manipulation before any analysis can take place. The query and analysis results can finally be displayed on a map.

### GIS Software Categories

Different types of GIS software exist with different functionality, as not every GIS user needs to carry out all the above tasks. For instance, an employee in the public services department of a city may only provide information on house owners to construction companies and may not need to edit the cadastral data set.

Figure 2 summarizes commonly used GIS software categories. Desktop GIS usually serves all GIS tasks and is sometimes classified into three functionality categories: (1) GIS Viewer, (2) GIS Editor, and (3) GIS Analyst. Spatial Database Management Systems (DBMS) are mainly used to store the data but often also provide (limited) analysis and data manipulation functionality. WebMap Servers are used to distribute maps over the Internet. Similarly, WebGIS Clients are used for data display and to access analysis and query functionality from Server GIS over the Internet or intranet. Libraries and Extensions provide additional (analysis) functionality that is not part of the basic

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<th>GIS Task vs. Software</th>
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<th>editing</th>
<th>storage</th>
<th>conflation</th>
<th>transforming</th>
<th>query</th>
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**Figure 2** Typical tasks accomplished with different GIS software

*Source: Stefan Steiniger.*

*Note: ● = standard functionality; ○ = optional functionality.*
GIS software—for instance, functions for network and terrain analysis or functions to read specific data formats. Finally, Mobile GIS is frequently used for field data collection.

GIS WEB SERVICES

GIS software is provided not only by companies but also increasingly by free and open-source software projects. While commercial vendors usually offer products for all software categories, open-source software projects often concentrate on a single category, for example, desktop GIS or WebMap server. The key players in the GIS software market today are Autodesk, Bentley, ESRI, Inc. (Environmental Systems Research Institute), GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph. GIS software companies tend to target specific application domains. For instance, ESRI’s ArcGIS product tends to be mainly used for business analysis, planning, and environmental applications, while Autodesk, GE, and Bentley products are used in utility and facility management. Competitive GIS software that is developed by free software projects exists as well—especially with respect to server applications (MapServer, GeoServer) and spatial DBMS (PostGIS). Free desktop GIS projects, such as Quantum GIS and gvSIG, currently have growing user communities.

Stefan Steiniger and Robert Weibel

See also Database Management Systems; Data Querying in GIS; Geospatial Industry; GIS, Environmental Model Integration and; GIS Implementation; GIScience; GIS Web Services; Open Source GIS; Spatial Analysis; Spatial Data Integration; Spatial Data Models; Spatial Decision Support Systems; Web Geoprocessing Workflows; Web Service Architectures for GIS

GIS WEB SERVICES

Geographic information system (GIS) Web services represent an evolution of traditional stand-alone GIS applications available in desktop environments with database back-ends for storing data, and they provide the components for a spatial data infrastructure (SDI). GIS Web services are self-contained application components that are published and accessed over the World Wide Web using standard protocols such as HTTP, SOAP, and XML. Each service performs a specific GIS function as part of a loosely coupled and distributed geographic application (also called a distributed GIS).

The functionalities provided by GIS Web services can be classified into four basic categories—geographic data discovery, access, computation, and visualization—which are described in the following sections. Additional functionality is required to orchestrate the interaction among several services in order to provide specific applications. GIS Web services categories and orchestration are illustrated in Figure 1.

The main challenge in using GIS Web services is that they require an agreement on a common architecture and a portfolio of standard Web services to support reusability and create applications that share the use of services. Emerging interoperability specifications, in particular from the Open Geospatial Consortium (OGC), have addressed this challenge.

Discovery

Discovery services enable the ability to publish, query, and retrieve descriptive metadata for
resources, which can be data and services. A discovery service is significant for the establishment of an SDI, as it enables users to discover which data and services exist and could potentially be used in a given application. Metadata offered by such a service should include descriptions of the content and functionality, quality information, and access details and/or restrictions that enable a user to evaluate fit for the purpose of the resource.

A prominent specification of discovery services is the OGC’s Catalogue Services Specification, which offers a range of service interfaces that support the discovery, access, maintenance, and organization of catalogs of geospatial resources. Various profiles of the catalog specification offer different bindings for protocols—among others, HTTP and SOAP.

Current catalog implementations mainly rely on matching keywords with metadata entries, leading to low recall and/or precision during search. They do not yet make use of semantic Web technologies.

OGC provides several specifications of services for geodata access. The Web Feature Service (WFS) and Web Coverage Service (WCS) provide access to vector data and coverages, respectively. These services provide access (read and write) and enable querying of geographic data using a standardized interface. To support exchange of data between a client and a service, the Geography Markup Language (GML) has been proposed by OGC as an encoding of geographic data. GML is an XML (EXtensible Markup Language) grammar that can be used to represent both discrete features (vector) and continuous-coverage surfaces (raster). Keyhole Markup Language (KML) is an alternative XML-based encoding, now also an OGC standard. WFS uses GML as data exchange encoding, and WCS can use GML but also supports traditional binary formats such as JPEG, (geo)TIFF, and PNG.

**Computation**

The computational capability of GIS is important for any kind of geographic analysis. Traditional GIS offer a vast amount of computational functionality, which needs to be transposed into the Web services platform to enable distributed GIS. In principle, any kind of GIS functionality can be exposed on the Internet as a Web service, using standard protocols and bindings such as HTTP and SOAP. The main challenge is to standardize these components in order to facilitate interoperability, that is, standard ways to invoke services and encode data and messages among services.

Standardized encoding of data, such as GML and KML, enables interoperable exchange of data not only between a client and a service but also among Web services, for example, for geographic data computation. In addition to the encoding of data, OGC has published the Web Processing Service (WPS) specification for standardizing an interface for geographic data computation. It offers a generic interface that can be used to invoke a variety of computational functionalities for geographic data (vector as well as raster). Examples of computational functionality are statistical or geospatial calculations, image processing and analysis, and, in general, computer algebra operations.
**Visualization**

A fundamental requirement for working with GIS is the possibility of displaying and portraying geographic data as maps. For a distributed GIS, visualization services are required to visualize data or results from computation services. OGC specifies the Web Map Service (WMS) interface, which can be used to visualize data accessible through data access services such as WFS or data stored within the WMS itself. The data can be visualized using a predefined or user-defined symbology.

**Orchestration**

To support a distributed GIS, there is a need for controlling the interaction among various GIS Web services. An example here may be an application where data are retrieved from a geodata access service, manipulated by a computation service, and finally portrayed in a visualization service. This workflow can, in its most simple form, be controlled by a client. However, more advanced technologies are available. Workflow languages such as Business Process Execution Language support the (parallel or sequential) execution of different service invocation activities, conditional behaviors, activities related to events, and the definition of new service interfaces used to exhibit the implemented functionalities. Therefore, workflow languages enable the definition of new GIS Web service interfaces with their own interfaces based on distributed service components.

Anders Friis-Christensen

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**GLACIERS: CONTINENTAL**

The term glacier originates from the Latin word glacies, meaning “ice,” and refers to any body of perennial ice originating on land through the densification and recrystallization of snow that is massive enough to be flowing under its own weight. Generally, glaciers form in areas where the annual accumulation of snow, through precipitation and deposition, is greater than the annual mass loss due to melting, sublimation, and the calving of icebergs at the glacier margin. Glaciers provide important stores of water to more than 40% of the world’s population, maintain the temperature of the planet through a high albedo (they reflect sunlight back to space), and, in the case of the largest bodies of ice, even affect local and regional climate.

Glaciers form where the snow accumulates for hundreds to thousands of years. As the snow accumulates, older layers of snow are buried beneath more and more mass and are eventually compressed and recrystallized into dense glacial ice (density = 917 kilograms per cubic meter). If enough mass accumulates, the ice begins to flow downhill and outward toward the margins, where mass is lost.

Mass loss on a glacier is known as ablation. Anywhere on the glacier or ice mass where annual ablation exceeds accumulation is included in the ablation zone. Areas where accumulation exceeds ablation are included in the accumulation zone. The equilibrium line separates the accumulation and ablation zones and marks where accumulation and ablation are equal. This occurs at the equilibrium line altitude, which typically varies with latitude and the prevailing climatic conditions. On some glaciers, the highest elevation area may experience no melt at all. This area is referred to as the dry snow zone.

Glaciers occur in many places and in many different morphologies. The largest ice masses are ice sheets. Ice sheets cover continent-sized areas and are typically dome shaped. The surface morphology of ice sheets, unlike that of mountain glaciers, is relatively unaffected by the underlying topography. The flow of ice from these domes is outward from the summit, terminating in many outlet glaciers along the ice sheet margins. These outlet glaciers typically are constrained by the topography.

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See also Distributed Computing; Geocomputation; Geospatial Semantic Web; Interoperability and Spatial Data Standards; Metadata; Mobile GIS; Neogeography; Open Geospatial Consortium (OGC); Spatial Data Infrastructures; Web Geoprocessing Workflows; Web Service Architectures for GIS

Further Readings

OGC—OpenGIS Standards and Specifications: www.opengeospatial.org/standards
At present, there are three large ice sheets on Earth, namely the West Antarctic Ice Sheet, the East Antarctic Ice Sheet (Figure 1), and the Greenland Ice Sheet (Figure 2). Combined, these ice sheets contain more than 90% of the estimated 33,000,000 km³ of ice contained in all the glaciers in the world. The ice thickness on the East Antarctic Ice Sheet exceeds 4,200 m (meters) in places, while the West Antarctic Ice Sheet is grounded mostly below sea level and may be up to 2,500 m below sea level in places.
Ice caps are also dome shaped but are much smaller in scale. They typically occur at higher elevations but have morphologies similar to those of ice sheets, also terminating in outlet glaciers. In fact, very little differentiates ice caps from ice sheets, other than their size; their dynamics and flow characteristics are nearly identical.

Outlet glaciers from ice sheets and ice caps may terminate on land or in the ocean, where they are referred to as tidewater glaciers. A glacier becomes tidewater at the grounding line, the point where the base of the glacier becomes ungrounded, or disconnected from the land beneath. As glaciers flow out over the water, there is less friction at the base, and their flow accelerates. This divergence of mass leads to thinning and spreading of the glacier where it is unconfined.

In some cases, particularly around the Antarctic ice sheets, many tidewater glaciers terminate in a single bay, gulf, or sea. There, the ice may combine and flow out in a large sheet over the water, called an ice shelf (Figure 1). Ice shelves continually grow through the flow of ice out from the ice sheet and shrink through calving and breakups of the ice shelves at their edges, through surface melt and sublimation, and largely through basal melt. Studies of tidewater glaciers in Greenland suggest that more than 90% of the mass lost is through melt at their bases.

Ice shelves are thinner than the continental glaciers from which they are born but are much thicker than sea ice (Figure 1), which is ocean water that is frozen at the surface. While not technically a glacier, sea ice is also an important component of the cryosphere, particularly in how it reduces the coupling of the ocean and the atmosphere and alters the salinity of the ocean (salt sinks out of the ice, making the water both more saline and more dense); sea ice has a much higher albedo than the underlying water, affecting the radiation balance of the planet.

Glacier ice behaves as a slowly creeping fluid but also exhibits nonlinear flow like a brittle material. As a fluid, it deforms in a uniform fashion without momentum or turbulence. The glacier slowly changes shape as it deforms. Occasionally, the deformation speeds up, and fracturing may occur, resulting in the formation of crevasses.

In a joint meeting of glaciologists and metallurgists in England in 1948, it was realized that ice is a polycrystalline solid and should deform like polycrystalline metals and rocks close to their melting points. Prior to that, it was assumed that ice deformed like a Newtonian viscous body. As a polycrystalline solid with randomly oriented crystals, the deformation rate initially decreases with time as crystals with different orientations interfere with each other. As these crystal matrices deform and align more favorably for deformation (i.e., parallel to the applied strain), the deformation rate tends to settle into a steady-state value. The eventual recrystallization of the ice leads to an orientation more favorable for deformation,
As glaciers slide over their beds, they encounter bumps and other obstacles to flow. While the ice is driven around larger bumps through plastic flow, sliding over smaller bumps is usually achieved through an exchange of heat and water around the bump. As the ice hits the upstream side of the obstacle, pressure builds up, lowering the pressure-melting point. This allows a layer of ice to melt and the water to flow past the obstacle. As the ice passes the downstream side of the obstacle, the pressure lowers, raising the pressure-melting point. This allows the water to refreeze, releasing latent heat. The latent heat released is absorbed on the upstream side as melting occurs. This process, known as regelation (see Figure 3), is only possible where the obstacle is small enough to allow for the efficient transfer of latent heat across it. Once the obstacle becomes too large, plastic flow occurs.

The rate of deformation on a glacier is strongly dependent on the internal temperature of the ice. Temperature at the base of the glacier helps control erosion. When ice is frozen to the bed, it is protected from erosion. As basal temperatures increase, melt increases, increasing the basal sliding rate and allowing more erosion.

At any given point on a glacier, the temperature profile may be considered “cold,” where all

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**Figure 3** The process of basal sliding over an obstruction via regelation

ice is below the melting point, with the possible exception of the base; “polythermal,” where a finite layer at the base is at the melting point; or “temperate,” where the ice in the top 10 to 15 m is below the melting point. The temperature distribution within the glacier is controlled by heat transfer into, out of, and within the ice mass. The main controls on ice temperature include the shortwave and long-wave radiation balances at the surface, the exchange of latent heat at the surface mainly from sublimation and deposition on cold glaciers, the turbulent transfer of sensible heat between the air and the ice surface, and the subsurface heat flux, particularly from geothermal heat and friction from sliding. The refreezing of percolating meltwater liberates additional latent heat, while melt at the surface results in the absorption of latent heat from the surface.

Seasonal variations of temperature at the surface are dampened with depth in the ice. By a depth of 10 to 15 m, the ice temperature often resembles the mean annual surface temperature. In dry-snow zones, where the surface temperature remains below freezing all year, this mean annual temperature is generally reached at a depth of 10 m. Where melt does occur, the refreezing of percolating meltwater at depth releases latent heat, significantly inflating the 10-m temperatures. The amount of temperature added to depth varies from year to year depending on the amount of melt. In the ablation zone, all the superimposed ice that forms melts off by the end of the ablation season, so any increase in the 10-m ice temperature is temporary as the excess heat is reabsorbed by the ice as it melts. Accordingly, 10-m temperatures may be colder in the ablation zone, even though the air temperatures are warmer.

As glaciers melt or grow, they have a direct effect on sea level. At the height of the last glaciation, 20,000 yrs. (years) ago, mean sea level was approximately 120 m lower than at present, mainly due to the presence of the Laurentide Ice Sheet over North America but also due to the Scandinavian Ice Sheet and the expansion of the Greenland and Antarctic ice sheets. As the last glaciation gave way to the present interglacial stage, sea levels rose at an average rate of 10 mm yr.−1 (millimeters per year), from 15,000 yrs. ago to 6,000 yrs. ago. This rise was not steady, but episodic and dynamically driven. In contrast, sea levels have not fluctuated much more than 50 centimeters in the past 6,000 yrs. In the 20th century, sea levels rose at an average rate of 1.5 mm yr.−1, the fastest rate in the past 6,000 yrs. Approximately half of this rise is attributed to thermal expansion of the oceans. The other half is attributed to the melting of glaciers and ice caps.

Evidence of past glacializations is found in the isostatic response of Earth’s crust as well as in the remnant glacial features. As a large ice sheet grows, it depresses Earth’s viscoelastic crust beneath it. When the ice melts, the crust rebounds over thousands of years, leaving evidence of prior loading, which can help determine the size of the ice sheet but complicates determining the changes in sea level.

Glacializations also leave behind telltale geomorphic features such as moraines and striations. Moraines are localized deposits of material carried by a glacier. As glaciers advance, material is pushed forward. When they retreat, they frequently leave a mound of material at the maximum extent of their snout. These deposits can help determine the maximum extent of the glacier or ice sheet. Lateral moraines, occurring on hill-sides or mountains, yield evidence of the elevation of past glaciers. Glacier striations, gouges in rock from the sliding of a glacier with entrained material, can indicate the flow or orientation of former ice motion.

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See also Fjords; Glaciers: Mountain; Ice; Permafrost; Poles, North and South

Further Readings


In mountainous locations where more snow crystals accumulate annually than melt, a glacier will form. Glaciers develop from the accumulation of snow; when this accumulation reaches a sufficient thickness, glacier ice forms. Under its own weight and the force of gravity, the snow and ice begin to move, and a glacier is born. Mountain glaciers attract our attention because they have created much of the beauty of alpine regions, creating cirques, alpine lakes, U-shaped valleys, horns, and arêtes. These glaciers are important in many alpine regions, as they are a key component of summer stream flow, providing runoff for irrigation, hydropower, and drinking water during the driest months of the years to many of the world’s largest rivers. Mountain glaciers affect the sea level, lowering it as they expand and raising it as they contract. Glaciers are also noteworthy for their sensitivity to climate, as indicated by their response to the recent rise in global temperature, which has prompted widespread and ubiquitous retreat in the alpine regions.

Glaciers form where snow and ice accumulation exceed snow and ice melt. As the snow and ice thicken, there will be a point where the mass begins to move due to a combination of the slope the snow is lying on and the pressure of the overlying snow and ice. On steeper slopes, this can occur with as little as 20 m (meters) of snow-ice. There are two types of mountain glaciers, based on their temperature: polar and temperate. A polar glacier has cold ice throughout, never reaching the melting point; these glaciers are confined to the Arctic region and very high-altitude locations with dry climates. A temperate glacier is at the melting point throughout. The snow that forms temperate glaciers is subject to repeated freezing and thawing, which quickly changes it into rounded granular ice, or firn. Over a period of years, the firn undergoes further compaction, as well as grain growth via melting and refreezing, and sinters together with neighboring firn grain, creating glacier ice with air bubbles trapped between the grains. This process takes from 3 to 10 years on temperate glaciers, depending mostly on the accumulation rate—the higher the accumulation rate, the faster the process. On a polar glacier, without the melting and refreezing, the process takes much longer. The accumulation rate is lower on polar glaciers as well, further slowing the process of firn and glacier ice formation, which now must occur mainly via compaction.

The smallest alpine glaciers form high on the mountain slopes and are niche, slope, or cirque glaciers. These glaciers occupy locations that favor snow accumulation from drifting or avalanching and/or provide some radiational shading. As a mountain glacier increases in size, it can begin to flow downvalley, creating a valley glacier. Larger alpine glaciers can merge into a large area, covering a portion of a mountain range; these are ice caps or ice fields, such as the Barnes Ice Cap, Baffin Island, or Juneau Icefield, Alaska. In Patagonia and Alaska, large outlet glaciers from ice fields reach the ocean, to become tidewater glaciers. The larger glaciers, like rivers, are formed from tributary glaciers joining together into a larger trunk outlet glacier.

Glacier Movement

Mountain glaciers tend to have high slopes, as the terrain they exist in has substantial relief. Flow rates range from a few meters per year on small cirque glaciers to 10 meters per day on large tidewater glaciers such as Columbia Glacier, Alaska, and San Rafael Glacier, Chile. Surging glaciers are an unusual exception; they flow relatively slowly for many years and then flow quite quickly for a few weeks to a year. Glaciers move by sliding...
over their bed and by internal deformation. Steeper slopes and thinner ice increase the percentage of motion from sliding, thick glaciers, and low slopes increase the role of internal deformation. Sliding occurs when a thin layer of water at the bottom of the glacier sufficiently reduces friction. This water may come from basal melting due to the pressure of the overlying ice or from surface meltwater that has worked its way through cracks in the glacier. Velocities are highest at the surface and in the middle of the glacier, where frictional impacts are at a minimum. This leads to the highest erosion in the center of the glacier and the valley or basin underneath. Many glaciers flow faster during summer, when more meltwater is produced; this is a sure sign that basal sliding is the main mode of flow.

The active glacier flow results in the formation of crevasses. Crevasses form where a differential in glacier motion leads to the development of surface separation. If a glacier accelerates as slopes steepen, transverse crevasses form. When a glacier can expand laterally, longitudinal crevasses will develop. At the lateral margin of a glacier, the friction of the sidewalls slows a glacier, resulting in splayed crevasses. If a glacier is sufficiently thick and descends a steep slope, an icefall will develop.

Lyman Glacier, Washington. The lake in the foreground is colored green by glacier flour from glacier erosion. This is a small cirque glacier fed by avalanches from the mountain above. Crevasses indicate glacier flow. The separation between bare blue glacier ice and snow cover is also evident. The photograph, taken in 2008, is from the 1944 terminus position of the glacier.

Source: Author.
Glacier Mass Balance and Terminus Response

As a glacier develops and flows downslope, it balances the excess accumulation that created it with additional ablation, terminating where there is a balance between accumulation and ablation. A glacier is divided into the accumulation zone, where accumulation persists through the summer season, and an ablation zone, where snow cover is seasonal. The two zones are separated by the equilibrium line. A typical mountain glacier must have an accumulation zone that is at least 60% of its total area. If a glacier is calving, the percentage increases.

The health of a glacier is determined by monitoring the behavior of the terminus and/or its mass balance. Glacier mass balance is the difference between accumulation and ablation (melting and sublimation). Climate change may cause variations in temperature and snowfall, altering the mass balance. A glacier with a sustained negative balance is out of equilibrium and will retreat. A glacier with sustained positive balance is out of equilibrium and will advance to reestablish equilibrium. Glacier advance increases the area of a glacier at lower elevations, where ablation is highest, offsetting the increase in accumulation.

Glacier retreat results in the loss of the low-elevation region of the glacier. Since higher
elevations are cooler, the disappearance of the lowest portion of the glacier reduces the total ablation, increasing the mass balance and potentially reestablishing equilibrium. If the mass balance of a significant portion of the accumulation zone of the glacier is negative, the glacier is in disequilibrium with climate and will melt away without a climate change toward cooler, wetter conditions.

**Glaciers and Water Supply**

Temperate mountain glaciers are an important water resource. The meltwater generated above the equilibrium line percolates through the snowpack, slowly reaching the internal drainage system of the glacier. In the ablation zone, meltwater flows in supraglacial streams on the surface, usually descending into the glacier via a moulin or a crevasse. The water then is carried through the glacier englacially or may reach the base of the glacier. The internal drainage system develops during the course of the summer and is quite remarkable in that the majority of the runoff will congregate into a single outlet stream at the glacier terminus. The glacier runoff that is discharged peaks during dry, warm periods during the summer melt season, when other contributors to runoff are at a minimum. The runoff is also rich in glacier flour, generated from erosion of rock at the base of the glacier. Glacier runoff often provides up to 50% of flow during
late summer in rivers draining glaciated mountain regions.

**Glacier Distribution**

Glaciers exist on every continent. In Oceania, glaciers exist on New Zealand’s South Island; the New Zealand Alps are host to numerous glaciers. New Zealand has more than 3,000 glaciers covering 1,160 km² (square kilometers). In New Guinea, several small glaciers are located on its highest summit massif, Puncak Jaya, with an area of 3 km², though these glaciers are rapidly disappearing. Africa has glaciers on Mount Kilimanjaro in Tanzania, on Mount Kenya in Kenya, and in the Ruwenzori Range of Tanzania. African glaciers have an area of 6 km² and are all retreating. South America has 25,000 km² of mountain glaciers, 90% in Chile and Argentina. Glaciers occur along the entire crest of the Andes from Colombia south to Chile and Argentina. In the northern portion of the Andes, many of the glaciers are at very high elevations, with snowlines from 4,500 to 5,000 m, existing in a dry climate with little snowfall or melting. At the southern end of the continent, large outlet glaciers of Patagonia’s ice fields terminate in the ocean, with snowlines ranging from 300 to 1,500 m. In Central Asia, ice cover is estimated at 115,000 km². The majority of glaciers are in the Himalaya and adjacent mountain ranges, Karakoram, Kunlun Shan, Pamir, and Tien Shan. These glaciers are key sources for the largest rivers of Asia, the Ganges, Brahmaputra, Indus, and Yangtze Rivers, for example. Kamchatka

**Figure 1** Annual mean glacier mass balance in water equivalent to glacier thickness gained or lost, as reported to the World Glacier Monitoring Service

*Source:* Created by author, from data compiled by World Glacier Monitoring Service.
has nearly 3,000 km² of glaciers, mostly on the flanks of volcanoes.

Glaciers are a key aspect in the development of the environment of the Alps in Europe. The glaciers carved the mountain valleys, gouging out the alpine lakes, steepening the famous mountains, providing key water resources for hydropower and drinking. The Alps and the Caucasus have 3,800 km² of glacier ice. In the Pyrenees, two thirds of the ice cover has been lost since the 19th century, with retreat particularly rapid since 1980. Norway and Sweden lost 2,900 km² of glacier-covered area. In Norway, 15% of the water used is from glacier runoff, particularly for hydropower. In North America, glaciers occupy the coastal ranges from the Sierra Nevada, California, north through the Cascades to the Coast Range of British Columbia and Alaska. The Rocky Mountains and affiliated ranges are glaciated from Mexico north to the Yukon; there is 124,000 km² of glacier cover. Much of the glacier cover is remote, but many glaciers are crucial to water supply. The Columbia River, renowned for its salmon and hydropower, is heavily fed by glacier runoff. In the Arctic, glaciers are a mixture of ice caps in nonmountainous areas and mountain glaciers. From Iceland to Baffin Island and Novaya Zemlya, glaciers cover 275,000 km². Except on Iceland, the Arctic glaciers are not much used as a water resource.

### Recent Glacier Behavior

Repeated observations of a glacier’s terminus allow determination of its behavior. Glacier termini that lack active crevassing indicate a lack of active flow in the terminus area; these glaciers will be retreating. The World Glacier Monitoring Service (WGMS) collects terminus change data throughout the world. In 2005, of the 442 glaciers examined and reported, 388 were retreating, 18 were stationary, and 26 were advancing. The 90% retreating figure is less than the total percentage of retreating glaciers, as the number of glaciers in the Himalayas and Alaska, where retreat has been widespread, is underreported.

Mass balance is also assessed on a number of glaciers by measuring both the accumulation and the ablation across a glacier. The WGMS collects these data annually; from 1975 to 2005, the average glacier lost 0.30 m of thickness annually. This cumulative loss of 10 m sliced off the average glacier is a modest amount on large glaciers but a critical amount on small glaciers averaging 20 to 40 m in thickness. This loss also contributes substantially to global sea-level rise (see Lyman Glacier image).

During the Little Ice Age, from about 1550 to 1850, the world experienced relatively cooler temperatures compared with the present, and glaciers advanced. Subsequently, until about 1940, glaciers around the world retreated as the climate warmed. Glacial retreat slowed and even reversed, in many cases, between 1950 and 1980, as slight global cooling occurred. However, since 1980, significant global warming has led to glacier retreat becoming increasingly rapid and ubiquitous. This has led to the disappearance of some glaciers, and the existence of a great number of the remaining glaciers of the world is threatened. In locations such as the Andes of South America and the Himalayas in Asia, the decline of glacier area will reduce summer water supplies. Glaciers act as large natural reservoirs, slowly melting during dry warm periods. As their size is reduced, the area exposed for melting decreases, reducing the capacity of these frozen reservoirs.

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*See also* Anthropogenic Climate Change; Climate Change; Fjords; Geomorphology; Glaciers: Continental; Ice; Permafrost

### Further Readings


Throughout geologic history, Earth has experienced dramatic environmental changes from forces such as plate tectonics and glaciation. However, recent human activities have accelerated the rate and scale of global changes immensely—so much so that many authorities now suggest that the Holocene is ended and a new geologic epoch has been entered: the Anthropocene. Human impacts on Earth have multiplied as technology develops and populations grow. The rate of change has increased much faster than just the population growth rate, as humans have moved from merely procuring food and shelter to exploiting Earth for myriad products to add comfort to their lives and to using increasingly advanced technology that creates a variety of waste products. Global environmental change encompasses the study of all these anthropogenic impacts on Earth. Global environmental change includes global climate change and more regional changes such as urbanization, ozone depletion, soil erosion and land degradation, desertification, habitat alterations, deforestation, hydrologic perturbations, and other changes that directly affect ecological systems.

Institutions and governance of local societies often dictate the rate and regional impacts of global environmental change. These changes manifest themselves at multiple spatial, temporal, and sociopolitical scales, and it is this complexity that makes examining the entire phenomenon so difficult. Current research in global environmental change is concerned both with documenting change and the interactions of forcing mechanisms as well as with mitigating their impacts. Environmental change mitigation is accomplished by reducing societal and ecological vulnerability to disruption by maximizing the resilience and adaptive capacity of the systems.

Land Cover and Land Use

Every organism changes its immediate environment to suit its habitat needs. However, humans change Earth as no other species in the geologic record has done. Throughout history, deforestation has been driven by the local civilization’s land use intensity, as the demand for timber products has often intersected with the demand for agricultural land to dramatically alter landscapes. These impacts are exacerbated by climate, fire, and insect disturbances. Human impacts on land cover have a variety of climatic, ecological, and socioeconomic drivers, and landscape fragmentation often results. Biological impacts such as
changes in the assemblage of species, local extinctions, dispersal, and relocation also result from local changes in habitat parameters. Land use changes transform the land’s productivity and biochemical/hydrologic cycling. The most profound alteration has been the conversion of various land types to agricultural uses, so that now, over one half of Earth’s potential agricultural land is already in use.

At a global level, change from a dark forest to lighter soil changes the albedo of Earth’s surface and the resultant radiative forcing. Carl Sagan theorized that the Little Ice Age in Europe was partially caused by such a regional clearing of forest for agriculture and the resultant albedo effect. In addition to albedo, land cover changes affect runoff rates, soil erosion and sediment deposition, habitat availability, and local microclimates. These processes also affect transpiration (through the loss of vegetation) and surface latent and sensible heat fluxes. Local sources of precipitation, or recycled rain, can account for one third or more of rainfall—the Amazon has the highest values in the world—and deforestation reduces transpiration, which in turn reduces local precipitation.

The most significant causes of land cover change globally, ranked by area affected, are grazing (because it uses marginal lands across nearly 50% of the planet—from deserts to mountains to subpolar regions), agriculture, timber activity, and urbanization. Combined, these impacts have accelerated the global extinction rate by fragmenting habitat, and this favors rapid growing of pioneer species that are adapted to the broadest range of physical conditions. It is estimated that one third or more of Earth’s species may go extinct in modern times due to global environmental changes in species habitat.

Soil Degradation
Soil quality is the inherent capability of soil to perform environmental functions, and degradation may result in the partial or complete loss of soil’s productive capacity. Global soil degradation includes erosion, compaction, acidification, soil organic matter and fertility losses, and salinization. Mismanagement of soils for agriculture, timber activity, and by livestock owners is the major cause of soil degradation. Estimates of global soil degradation suggest a 25% to 50% loss of global productivity resulting from human impacts on soils. The most well-known example of soil degradation is desertification, which is the degradation of formerly productive lands into deserts. This process was addressed by the United Nations Convention to Combat Desertification in 1994, but other aspects of soil degradation have not been addressed at the international level.

Water Resources
Humans affect water quantity and water quality both above- and belowground, and these issues are interrelated. In the case of water quantity, water diversion for irrigation consumes 70% of the water used globally and has stopped or impaired the flow of many rivers worldwide. To regulate water supplies, dams, canals, and dikes have been constructed, and river channel alterations have been undertaken on nearly every river of the world. Engineering channel processes significantly alters hydrologic function, changes sediment delivery patterns, and disrupts riparian habitat stability. Land use changes affect water resources, as deforestation impedes hydrologic processes, leading to local decreases in precipitation and more rapid runoff, which, in turn, lead to greater flooding and increased soil erosion.

There are several other major issues of water quality as well. Grazing, agriculture, forestry, and construction all contribute sediment to rivers and disrupt channel morphology and aquatic photosynthesis. Agricultural chemical runoff includes both pesticides and fertilizers: Nitrates and potassium come from fertilizer application and livestock fecal matter. Storm water runoff from roads and parking lots is another major source of nonpoint water pollution. Point source pollution from urban areas is still widespread in much of the world and includes sewage and industrial waste disposal. Groundwater depletion from overpumping of wells is a growing problem as precipitation uncertainty grows with climate change and societies try to find more “secure” water supplies. The use of underground injection wells for storm water removal increases the risk of groundwater contamination in some areas. Polluted water is effectively unavailable for many uses, and thus water
quantity is intimately tied to water quality for
human use and ecosystem functions.

**Urbanization**

Urbanization’s most immediate impact is habitat
fragmentation and loss of agricultural lands and
forests as they are covered in impervious surface.
These surfaces retard infiltration and, combined
with storm sewers, maximize runoff into down-
stream waterways, which exacerbates flooding.
Additionally, oil, natural gas, sediment, and other
contaminants in storm water compromise water
quality and impair aquatic habitat. A second
major effect of increased impervious surface is to
create an “urban heat island effect.” This local-
ized elevated temperature potentially leads to air
temperature inversions and related air quality
impairment. Also, elevated precipitation develops
downwind from the urban area due to convective
effects and elevated cloud condensation nuclei
from particulate matter pollution. Urbanization
changes surface roughness, which affects air
momentum and heat transport.

**Ocean Change**

The vast size of the oceans has hindered quantifi-
cation of oceanic biogeochemical characteristics
and of recent environmental changes. The oceans
redistribute large amounts of heat around the
globe, and perturbations to ocean currents or
giant ocean gyres could change regional climate
patterns. The Younger Dryas was a cooling of the
Northern Hemisphere approximately 12,000
years ago, at the end of the Pleistocene. It was
marked by a slowdown of the global thermoha-
line ocean circulation (also known as the meridi-
onal overturning circulation), and a similar event
is expected under most climate change scenarios,
as the Greenland ice cap contributes massive vol-
umes of freshwater to the North Atlantic and
disrupts this ocean current. Recent studies indi-
cate that the subpolar North Atlantic gyre is in
fact slowing and cooling, but future trends are
uncertain. El Niño/Southern Oscillation is a qua-
si-periodic reversal of equatorial winds along the
equator in the Pacific. This cyclic instability dis-
rupts precipitation patterns and fisheries across
much of the world, and recent decades have seen
disruptions in the periodicity of the normal 3- to
5-year pattern.

Sea-level rise has been occurring for several
decades as ice caps and glaciers melt globally.
Sea-level rise is increasing coastal erosion and
leads to greater storm impacts inland. Ecosystem
and biodiversity impacts are driven by fishery
depletion from by-catch losses and pollution,
including sewage disposal, floating trash, and oil
spills. Recent uses of high-power sonar systems
for military purposes are expected to have cata-
strophic impacts on ocean mammals. Ocean
waters have become more acidic by more than
0.1 pH units, and increasing carbon dioxide
atmospheric partial pressure will further acidify
seawater. This leads to a reduction in aragonite
saturation in seawater and weakens carbonate-
secreting organisms’ shell structures, including
coral reefs. Ocean hypoxia is occurring in deltas
and estuaries of the world, as agricultural pollut-
ants and other chemicals reduce dissolved oxygen
partial pressures in seawater to near zero. The
occurrence of this phenomenon has increased
exponentially in recent years, and there are fears
of sterilization of some fisheries and ecosystems.

**Atmospheric Change**

Other atmospheric changes include ozone deple-
tion in the polar regions and acid rain. Anthro-
ogenic chlorofluorocarbons (CFCs) and bromine
compounds reduce stratospheric ozone concen-
trations in the presence of very cold temperatures
and have created ozone “holes” in both polar
regions. Ozone depletion impacts for terrestrial
species include sunburn, skin cancer, cataracts,
and loss of plant productivity. The impacts on
aquatic life in the Southern Ocean have not been
quantified but are expected to be equally severe.
Documented impacts on human and animal pop-
ulations are increasing exponentially in these
regions, even though CFC use has been phased
out globally under the Montreal Protocol on Sub-
stances That Deplete the Ozone Layer.

Acid rain is a regional phenomenon downwind
from major industrial areas burning fossil fuels.
Nitrogen oxide and sulfur dioxide emissions
remain in the atmosphere until they encounter
rain, snow, or fog to form sulfuric and nitric acids
and fall to the Earth as precipitation. Normal
rainfall is slightly acidic due to the presence of carbon dioxide in the atmosphere, but acid rain can exceed the pH of battery acid. This phenomenon can kill vegetation and sterilize water bodies—the German phrase for the phenomenon is “forest death.” Atmospheric deposition of compounds is not limited to acid rain; lead, mercury, radioactive fallout, and many other substances are delivered to the world’s ecosystems by air currents—there is no part of the world untouched by these human wastes.

### Biodiversity

Human-caused extinctions have occurred since at least the Pleistocene, when a large number of terrestrial megafauna disappeared as humans expanded their range into North America. Contemporary extinction rates and modeled future extinction rates are much more severe than past events and are not limited to a few organisms. Changes in habitat beyond environmental tolerance will cause more widespread taxa extinctions than past geologic events, because now there are fewer species dispersal routes. Life forms can respond to environmental changes through evolution, but the current rates of environmental change are far too fast for species’ response through such a mechanism. Extinctions result in the loss of genetic resources and also may impede future scientific research.

New ecosystems and assemblages of species are predicted to occur in the decades ahead in conjunction with massive species extinctions. Alien or invasive species are organisms that thrive when introduced into a new ecosystem and that often displace and even exclude many of the endemic species. The success of invasive species leads to a loss of biodiversity in an area and globally. Because they lack predators and competitors that have coevolved with them, they can spread rapidly and aggressively. Declines in biodiversity lead to a loss of natural capital and genetic material and, more important, a reduction in the ecosystem services that society critically depends on for survival. Ecosystem services do not have explicit values in our market-based economy, but steady losses will eventually make them infinitely valuable and ultimately unattainable. Habitat fragmentation is destructive to ecosystem services because trophic levels are more likely to be impaired or lost, especially in the upper trophic levels.

### Societal Implications

Humans affect the planet directly through resource extraction and waste release and indirectly through social systems including laws, regulations, and economic incentive systems. Social organizations and transnational resource flows have intertwined to determine local environmental change since colonization began. Humans extract up to 40% or more of global net primary productivity through grazing, logging, and agricultural systems, and a new societal emphasis on sustainability aims to ensure that these extraction rates do not have net global and local increases. Sustainable agricultural and forestry systems are affected as much by governmental policies and subsidies as climate parameters. Governments are searching for ways to balance economic needs with long-term social stability to mitigate global environmental change. Disruptions of socioeconomic activities in sensitive regions will cause migration as peoples flee inhospitable conditions and places and seek greater opportunities. These human migrations will inevitably, in turn, cause more rapid environmental change in the receiving areas. Governments are examining the military and political ramifications of these migrations and their expected increase as additional global environmental changes occur.

The major concern for society must be irreversible global environmental changes, because these mistakes cannot be remedied. Exploding species extinction rates are the most critical of the anthropogenic impacts because extinction is permanent and irreversible. Other changes are reversible but unlikely to be achieved (e.g., restoration of major temperate forests is very difficult because cities, homes, and farms would need to be removed). Soil losses are irreversible in many areas (within human lifetimes), but new soil can develop in other, less sensitive areas. Societal management of future environmental change will focus on understanding the role of global climate change in exacerbating environmental changes and on reducing the uncertainties in predicting the trajectory of future forcing mechanisms and the resulting changes.

John All
See also Acid Rain; Adaptation to Climate Change; Anthropogenic Climate Change; Biodiversity; Biogeography; Biota and Climate; Biota Migration and Dispersal; Carbon Cycle; Climate Change; Climate Policy; Climatology; Coastal Zone and Marine Pollution; Complexity Theory; Complex Systems Models; Desertification; Environmental History; Exotic Species; Extinctions; Global Sea-Level Rise; Great American Exchange; Human Dimensions of Global Environmental Change; Human-Induced Invasion of Species; Land Use and Cover Change (LUCC); Oceans; Plate Tectonics; Resilience; Symptoms and Effects of Climate Change

Further Readings


GLOBALIZATION

Globalization is a historical process of transnationalization, denationalization, and deterritorialization that encompasses different arenas, such as the economy, society, politics, culture, academia, and so on, with varying intensities and geographical differences. Loosely defined, it involves an increase in the scope, volume, and velocity of transactions across national borders, not all of which occur on a worldwide basis.

It is misleading to speak of globalization as a linear development, a fixed situation, or an undifferentiated worldwide phenomenon. Certain processes are, depending on world regions, globalized (such as trade, production, and labor and financial markets in the industrialized world), while others are constrained by local, regional, and national identities and policies (such as identity and border politics in sub-Saharan Africa; Central, East, and southeast Asia; and large parts of the greater Middle East). However, this status changes over time because the process of globalization is historically contingent. To take account of geographical differences, geographers have found the idea of globalizations (in the plural) increasingly relevant in recent years. Therefore, careful observation is necessary both to identify globalized arenas and to recognize the existence and assess the continuing relevance of national(ized) politics and (re)asserting statehood. Thus, the idea of a “borderless world” signifies some of the tendencies of contemporary hyperglobalization; depending on an individual’s standpoint, such globalization may be seen as either a positive or a negative development. Those arenas that can be made out as globalized, however, are characterized by three single, though interconnected, processes: transnationalization and, in its consequences, denationalization and deterritorialization. These processes are not linear but are contested and resisted by governments, regional organizations, and nonstate antiglobalization movements. Such resistance is directed at all kinds of globalizations, but it typically emphasizes economic issues such as labor rights, economic injustices, environmental degradation, and human rights violations. This entry examines these processes and their implications for local places.

The most far-reaching impacts of those transformations relate to (a) shifts in the structure of time and space; (b) conceptualizations of human agency, including power; and (c) political and geographical imaginaries of statehood. Although those impacts appear to be historically novel, they are comparable with earlier historical periods of social and political upheaval, including their geographical distinctiveness and impacts and their complexities.
Globalization and the Compression of Space and Time

Geographical distances can be overcome more easily and rapidly than ever before in history. The resulting compression of time and space has influenced the nature of the processes associated with globalization. This compression is largely due to new technologies of transportation and communications (e.g., developments in aircraft, telegraphic and telephone communication, and computer-based information technologies), the roots of which go back to at least the mid 19th century. These innovations allow for global coordination of social and political actions in simultaneous time; for example, through synchronized communication, people from (nearly) every corner of the world can get news of events at (nearly) the same time when they occur. Empirically, however, participation in those forms of communication and information flows is a question of their accessibility—that is, of social status and power; globalizations are much more widespread in the industrialized world than in less developed regions. However, the potential use of these innovations is, in principle, unrestricted. The compression of time and space also increases the permeability of borders in a wider sense—of territorial borders that control flows of people, goods, and information across nations and states. The porosity of borders also shapes transnational social organizations and movements. Because in democratic and pluralist political cultures the use of communications technologies is generally not restricted to certain classes or the elites, social participation in and use of their advancements in the industrialized world resulted in a massive increase of substate, global organizations during the late 20th century, for example, nongovernmental organizations. The growth in the number of such nonstate actors led to an increase in transborder social, political, and economic activities worldwide. These actors and their transborder activities, enabled by modern technology, play a key role in contemporary transnationalization and denationalization. The critical relevance of these two processes of globalization is that they call into question two major modern concepts of social, political, and economic order: the nation-state and international politics.

Transnationalization and Denationalization

Transnationalization (the emergence and increasing relevance of nonstate actors and their transborder activities) causes denationalization (shifts in decision-making power from nation-states to nonstate actors). Accordingly, the role, status, and power of states are increasingly uncertain and contested in the face of globalizations. This process has recently unfolded to a degree that is qualitatively new in world history. Since the Treaty of Westphalia in 1648, the nation-state and the international order in which it is embedded have formed the guiding principle of socioeconomic and political order for the past 350 yrs. (years) of Western and Westernized modernity. Thus, transnationalization represents a revolutionary upheaval in the conceptual focus that saw the world as divided by and compartmentalized into nation-states, world politics as limited to nation-states as actors, and the world as international, that is, involving interrelations only of and between nation-states (inter and nations). This focus on the nation-state, which dominated not only academic disciplines such as politics, sociology, geography, law, and economy but also nonacademic perceptions, became insufficient for understanding and managing globalizations. Globalizations forced the social sciences as well as people in everyday life to develop new concepts that grasp the threefold reality of social and political agency situated beyond the state, residing in and between states (including national politics of territorialization and reterritorialization), and constituted by tensions between states and global nonstate actors. This idea not only presents conceptual challenges for the social sciences and law and jurisprudence, whose basic ontological unit, the nation-state, is in a profound process of transformation, it also creates the epistemological necessity for large segments of society to identify and imagine normatively patterns of world order in which this ontological unit is becoming blurred.

The most common ontological unit discussed as a replacement, or substitute, for the nation-state and the international in globalized politics is that of networks. Transnational, global networks are replacing and acting concurrently alongside the nation-state and the international
order. Networks are functionally differentiated relations among a multitude of actors—nation-states, their governments, and public authorities; nonstate actors and transnational societies and movements; and individuals—that cooperate globally on specific issues. Actors gain access to networks or are recruited as network members as a result of their functional contribution to the overall network targets and their specific resources. Because networks transcend the nation-state and the international order, they contribute to the third component of the globalization process, namely, deterritorialization.

One important aspect of globalization is that it is fundamentally different from internationalization. Whereas globalizations rest on and create transnational (and deterritorial) networks of social exchange and politics, internationalization (and international politics and society alike) remains within the territorial framework of nation-states, referring to cooperation among, and solely between, nations and national sub-units. Thus, while the terms are often used interchangeably, they properly refer to different, if related, phenomena.

**Deterritorialization**

Deterritorialization, the third component of the globalization process, is a profound transformation of another basic ontological unit of the social sciences and common perceptions: territory and territoriality. In the 17th century, the primary form of political and social organization became associated with the nation-state, and this association became much stronger in the 19th and 20th centuries, when it was anchored in, and fixed to, the territorial framework of the sovereign state. Neither society, or politics or law in particular, nor human agency was perceived as possible without territorial fixation and a clearly demarcated geographical space where it was located and situated. The framework for territoriality was provided by the state, leading to geographical imaginations that equated statehood and national society. The basic political concept derived from this intellectual construction is sovereignty, which by definition is national sovereignty based on the geopolitical idea of a clearly demarcated territory; the basic sociological concept is integration, which is by definition the integration of a national society within a certain territory. Substantively intertwined with transnationalization and denationalization, the deterritorialization of distinct globalized geographical units such as nation-states fundamentally challenges the concept of territoriality so basic to political, social, economic, juridical, and geographical modernity. Transnationality and the exercise of human agency in globalized networks are not limited to territorial frameworks but frequently transcend the geographical spaces of nation-states and the international order. Transnational politics does not occur within individual states and cannot be understood by applying the concept of territorial sovereignty. However, it is too vague to speak of deterritorialization as such, and careful analysis is necessary to spell out its consequences and implications, which vary widely across the globe.

The consequences of deterritorialization can be specified by investigating the changing functions of borders. For the past 350 yrs., borders have been thought of primarily as territorial borders according to the paradigm of modern statehood. The functions of such borders have been defined in terms of ideology, sociopsychological considerations, legal issues, and the provision of military security. With regard to distinct multilevel forms of transnational activities, deterritorialization results in the partial dissolution and blurring of these traditional four rationales for borders. Empirical studies, however, reveal the ambivalent character of this transformation. While they typically retain their ideological and sociopsychological meanings, territorial borders have been increasingly replaced by the functional ties of transnational social, political, and economic networks; their relevance to national legal and security issues seems to have widely diminished. Territorial borders and frameworks are still important for legal stability and military security, because global law, transnational arbitration, and state-led privatization of security are without legislative power, ambivalent, and/or still under-conceptualized, and from the perspective of democracy, they often lack transparency and accountability. Thus, there still seems to be no substitute for the effectiveness, steadfastness, and reliability that have traditionally characterized territorialized and geographically delineated
(state) borders in (inter)national politics, society, and economy. Another indication of the continuing significance of territorial borders is that an estimated 80% of international wars have been and still are caused by border conflicts and territorial claims. Nevertheless, global (in)security, law, and jurisprudence are indeed borderless. Thus, there are large gray zones of lawlessness and insecurity both in the globalized arenas themselves and when the activities of globalized networks permeate into national and local societies. There are varying normative assessments of the development of borderless worlds; some see the potential for increased conflict as territorial boundaries become blurred, while others argue that de-bordering can foster new, grassroots-like forms of societal self-organization and transnational democracy.

Globalization, Networks, and the Human Subject

The most dramatic (and unresolved) philosophical consequences of the global transformation of time and space (dissolution of borders, compression of time and space) go hand in hand with those processes and are simultaneously reinforced by them. Globalization has had important implications for the nature of human identity and subjectivity. In most conceptualizations of modern political, social, and legal order, the human being is viewed as a self-contained subject, an autonomous person, and a unified (integrated) actor. This view assumes that the human subject is easily identifiable and is geographically and spatially constrained in terms of his or her inability to act simultaneously at two different locations. The rise of globalized networks, however, implies that the spatial and temporal scope of individual action is greatly increased and enhanced by new information and communications technologies, which allow individuals and networks to operate at multiple spatial scales. This transformation in potential geographical horizons can diversify the concept of the individual from an ostensibly self-contained subject, allowing him or her to occupy multiple, spatially different, contemporaneous spheres of being. When involved in globalized networks, individuals may multitask in several different contexts at the same time. While neoliberal imaginations of an independent economic subject whose primary function and identity are based solely on consumption sustain this discursive logic of globalization, and vice versa, there are in fact massive ruptures between the reality of functionally diversified individuals embedded in transnational networks and dominant existing concepts of human action with regard to political rights, legal claims, and social norms and values. Thus, one of the greatest challenges for the social sciences concerning globalizations appears to be imagining and normatively conceptualizing a deterritorialized society and politics, including the development of a theory of human action that lives up to the multifaceted realities of borderlessness and the globalized subject.

Globalization: Historical Context and Implications

When specifying globalization as a process of transnationalization, denationalization, and deterritorialization, it has to be acknowledged that such processes are not new phenomena but have many historical roots. Outstanding historical examples are world religions such as Protestantism and the Catholic Church; premodern political systems such as the Persian, Mongol, Chinese, Ottoman, and Roman empires, the Hanseatic League, and the 14th-century world system; and the globalization associated with European colonial conquests. Consequently, the question arises whether globalizations in the 21st century signify a mere quantitative proliferation or (also) a qualitative transformation—of transnationalizing, denationalizing, and deterritorializing political, social, and economic processes—as compared with their earlier historical forms. A necessary awareness of and sensitivity toward historical and empirical differentiation must not overshadow the fact that there are influential and highly transforming globalizations taking place in the early 21st century, bringing about qualitative transformations in world politics and geographies. Those qualitative changes are primarily due to revolutionary innovations in information, communications, and transport (technologies) that contribute to the three components of the globalization process (transnationalization, denationalization, and
determinitorialization) and the subsequent emergence of network societies and global flows of sociopolitical and economic communication and agency. The consequences of those upheavals are always in abeyance and ambiguous and can be identified only as transient, nevertheless eventually crucial, sociopolitical and geopolitical formations.

Hartmut Behr

See also Antiglobalization; Antisystemic Movements; Borders and Boundaries; Castells, Manuel; Colonialism; Debt and Debt Crisis; Decolonization; Dependency Theory; Deteritorialization and Reterritorialization; Developing World; Development Theory; Economic Geography; Emerging Markets; European Union; Export-Led Development; Export Processing Zones; Finance, Geography of; Glocalization; Gross Domestic Product; Gross National Product; Immigration; Imperialism; Import Substitution Industrialization; International Environmental Movements; International Environmental NGOs; International Monetary Fund; Marxism, Geography and; Modernization Theory; Nation; Nationalism; Neocolonialism; Neoliberalism; Newly Industrializing Countries; North American Free Trade Agreement (NAFTA); Offshore Finance; Organisation for Economic Co-operation and Development (OECD); Orientalism; Political Geography; Sovereignty; Space of Flows; Structural Adjustment; Supranational Integration; Telecommunications and Geography; Time-Space Compression; Tourism; Trade; Transnational Corporation; Transnationalism; Underdevelopment; War, Geography of; World Bank; World Cities; World-Systems Theory; World Trade Organization (WTO)


The global positioning system (GPS) is a satellite-based navigation system designed and operated by the U.S. Department of Defense (DoD). GPS can provide three-dimensional (3D) position and guidance in any weather and at any time of the day over the entire surface of the Earth, in the air, and in low space orbits. GPS consists of a control segment run by DoD, a space segment consisting of 24 or more satellites, and a user segment that includes military and civilian receivers.

GPS evolved from earlier regional and global radio navigation systems such as the Navy Transit System, Omega, and Loran-C. It was first described in the mid 1970s, and by 1985, there were enough satellites to allow development and testing of receivers for land, sea, and air navigation and guidance as well as for time and frequency dissemination and for both geodetic and plane surveying. The system was declared fully operational in 1995.

There is a wide range of GPS services and techniques with different capabilities, limitations, and
costs. There are two primary services that are provided by GPS and controlled by DoD. The Precise Positioning Service (PPS) is for use by the U.S. military, approved allied armed forces, and some agencies of the U.S. government. The PPS provides for encryption of the PPS bit stream (the P-Code) that is transmitted by the GPS satellites, mitigating the threat of spoofing, or tricking, a military receiver into tracking GPS-like signals transmitted by an adversary. Decrypting the PPS signals requires authorization and access to secure cryptographic keys.

The Standard Positioning Service (SPS) is now available, without restriction or charge, to everyone. For a time, between 1990 and 2000, the SPS bit stream (the C/A code) was intentionally degraded by Selective Availability to deny high-accuracy positioning to non-DoD users. The SPS, sometimes known as civilian GPS, is used throughout the world by a wide range of users in a wide variety of applications. Recreational hikers and boaters, users of automobile navigation systems, general aviation pilots, and data attribute collectors use inexpensive receivers to track the SPS signals.

The 24 or more GPS satellites orbit the Earth every 12 hrs. (hours). Earth rotates beneath the constellation, so the ground track of the satellites repeats in just less than 24 hrs. Monitored, adjusted, and provided with orbital and clock information by the control system, the satellites send their positions, their atomic clock errors, and complete system information on a bit stream called the Navigation Message. Relative ranges to satellites are determined within the receiver by lining up bit streams (P-Code and C/A code) sent by the satellites with identical codes produced in the receiver. The Navigation Message is sent from the satellites to the receiver over microwave frequency carrier signals that “spread” the SPS and PPS codes to resemble noise. When the receiver aligns its version of the codes with the noiselike GPS signals, the carrier frequencies are “despread,” providing the receiver with the contents of the Navigation Message and a code-phase relative arrival time for each satellite signal. Using at least four satellite messages and code-phase arrival times, a GPS receiver can produce a full 3D position solution and a correction for the receiver’s inexpensive clock.

SPS GPS can provide GPS receivers operating under optimal conditions with horizontal positioning errors of 3 m (meters) and vertical accuracies of 5 m. These levels of accuracy are 95% figures and require an antenna with a full and unobstructed view of the sky so that sufficient numbers of satellites and good enough geometry (satellites must be evenly spread out in the sky for robust positioning) can be obtained. Local reflections from building and ground surfaces can interfere with GPS tracking. Trees, some foliage, metal, many building materials, and even the human body can block GPS signals from getting to the GPS antenna with sufficient signal strength to allow for position determination. While there are some assisted and low signal–strength approaches to GPS receiver design, GPS remains an outdoor system requiring care on the part of the user to obtain useful position information.

Some GPS bias errors, including signal delays introduced by the ionosphere and troposphere, orbital parameter errors, and GPS satellite clock errors, can be reduced by applying corrections for each tracked satellite signal. Differential GPS (DGPS) uses corrections produced by one or more reference GPS receivers to improve the position accuracy of a remote receiver at an unknown position. The precisely located DGPS reference receiver produces corrections in the form of time-tagged range error and rate-of-range error parameters for each satellite along with codes identifying which orbital and clock parameters the corrections relate to. DGPS is not based on position corrections. The remote receiver position is computed after applying the range corrections for each satellite used in the remote receiver position solution.

DGPS is the basis for a wide variety of GPS approaches. Real-time, code-phase DGPS can make use of range corrections transmitted from ground-based or communications satellite radio transmitters. These real-time DGPS systems can provide 1-m accuracies when the receiver is within a few hundred kilometers of a DGPS reference station. Other systems such as the U.S. Federal Aviation Administration Wide Area Augmentation System provide corrections based on models for signal biases computed from a network of monitor receivers. These network solutions can result in 3-m accuracies anywhere within the national airspace service area of the system.
DGPS postprocessing can be accomplished if both remote and reference receivers store sufficient information to couple corrections with measured arrival times and orbital and clock data sets. Many commercial and public agencies provide Internet access to DGPS data for postprocessing. Geodesists use receivers separated by thousands of kilometers to measure tectonic movement by measuring over many hours. Surveyors make use of de-spread GPS carrier signals, low-noise receivers, special software techniques, and continuous tracking to produce relative position estimates over baselines of 10 to 30 kilometers.

Peter H. Dana

See also GIScience; GIS Web Services; Location-Based Services; Mobile GIS; Neogeography; Surveying

Further Readings


GLOBAL SEA-LEVEL RISE

Global sea level (i.e., the mean sea level averaged across the globe) has risen by 1.6 ± 0.2 mm/yr. (millimeters per year) in the period 1961 to 2003 and by a similar amount (1.7 ± 0.3 mm/yr.) when calculated over the entire 20th century. These rates are based on tide gauge measurements and, since the early 1990s, also on satellite altimetry. Satellite measurements have shown that global sea-level rise has not been uniform, either in time or in space.

The average global sea-level curve shows distinct temporal fluctuations. In the 1920s and 1930s, sea-level rise speeded up, while in the 1960s, sea-level rise slowed down. Since the 1970s, the maximum decadal rate of sea-level rise has increased from about 3 mm/yr. to more than 5 mm/yr. Averaged over the past 15 yrs., the global rate is about 3 mm/yr. The spatial pattern of sea-level rise shows large variability. Between 1993 and 2003, parts of the North Atlantic and Western Pacific oceans experienced rates of sea-level rise in excess of 10 mm/yr., but in the Eastern Pacific and Western Indian oceans, sea level fell by similar amounts. When averaged over the past 50 yrs. the pattern is also complex (Figure 1). Large parts of the world’s oceans have been subject to sea-level rise, but there are places, most notably in the Indian Ocean and the tropical Pacific, where sea level has fallen, albeit by a small amount.

Spatial variability in patterns of sea-level rise is strongly correlated with changes in oceanic heat content that affect the density of ocean water and produce so-called steric sea-level change. Thermal expansion is the predominant contributor to steric sea-level change; salinity variations are less important. Thermal expansion was responsible for about 45% of global sea-level rise in the period 1961 to 2003, with glaciers and ice caps contributing about 30% and ice sheets in Greenland and Antarctica a little over 10% each. Building of dams and mining of groundwater may be significant additional factors in the global sea-level budget but are believed to cancel each other out.

The melting of ice sheets, ice caps, and glaciers also produces regional sea-level variability, albeit on a larger wavelength than do the steric effects. The diminishing gravitational attraction exercised by a shrinking polar ice mass on the ocean surface causes sea-level rise to be greater in the “far field” (i.e., equatorial regions and the oceans in the opposite hemisphere) than nearby. This effect means that coastlines on both sides of the North Atlantic Ocean, for example, are more vulnerable to the melting of the Antarctic Ice Sheet than to melting of the Greenland Ice Sheet. The sloping pattern of sea-level rise produced by melting ice is known as the sea-level fingerprint of the melt source.

Coastal sea-level change is measured by tide gauges, but these instruments measure simultaneously the movement of the coast to which the
tide gauge is attached. Globally averaged rates of sea-level rise based on tide gauge records should therefore be corrected for isostatic and tectonic effects. The global glacial isostatic adjustment (GIA) process has been extensively analyzed with the help of sophisticated Earth models. These studies have revealed that GIA produces not only land-level changes but also a slow increase in the global ocean volume in areas where the ocean floor is subsiding due to glacial forebulge collapse and hydro-isostatic loading. The global sea-level fall due to this “ocean-syphoning” effect is about 0.3 mm/yr. and is important because it partly offsets the global acceleration of sea-level rise that has occurred between the 19th and the 20th centuries.

It is now becoming clear that humans are having a distinct impact on global sea-level rise. Computer simulations have shown that anthropogenic sea-level forcing took effect around the beginning of the 20th century. Since the 1950s, anthropogenic forcing has become more dominant than natural forcing. During the 19th century, sea-level rise was “natural” and slower. The climatic recovery following the volcanic eruption of Tambora in 1815 marked the onset of the global increase in oceanic heat content and the resulting thermal expansion. Aerosols produced by other large volcanic eruptions, including Krakatoa (1883), El Chichon (1982), and Pinatubo (1991), have temporarily cooled the ocean and halted global sea-level rise.

Figure 1  Linear trends in mean sea level between 1955 and 2003 determined from tide gauge data and satellite altimetry

The rates of global sea-level rise during the 20th and 21st centuries are small when compared with the episodes of sea-level rise during the last deglaciation. Around 14,000 yrs. ago, the event known as Meltwater Pulse 1a produced a short-lived sea-level rise in excess of 40 mm/yr. However, contemporary rates of global sea-level rise probably exceed the highest rates known to have occurred during the past 8,000 yrs., while during the Last Interglacial, when sea level was 4 to 6 m (meters) higher than today, rates of sea-level rise may have been as high as 0.6 to 2.5 m per century. These rates are comparable with the highest forecasts made for the remainder of the 21st century.

The Intergovernmental Panel on Climate Change (IPCC) has predicted that by the year 2100, global mean sea level will have risen by 0.18 to 0.79 m. This range reflects the possible greenhouse gas emission scenarios and their effects on the oceans and the cryosphere. These forecasts are made by sophisticated climate models, but higher rates have been predicted from extrapolating the empirical relationship between temperature and sea-level rise observed during the past century. However, these high rates have been challenged based on glaciological grounds, and it is considered unlikely that sea-level rise in the next 100 yrs. will exceed 1 m. Incorporating the dynamics of rapid ice decay into the modeling of sea-level change is required to improve future predictions of global sea-level rise. The regional variability of sea-level rise, so evident in the patterns of recent sea-level change, also needs to be included in future model predictions. In addition to rising sea levels, the frequency of extreme sea levels and storm surges is predicted to increase. The “smooth” line predictions of the IPCC can therefore be somewhat misleading. It is to be expected that in future decades, as in the 20th century, global sea-level rise will be of a fluctuating nature and the magnitude of local sea-level rise will be site specific.

Roland Gehrels

Further Readings


GLOBAL WARMING

See Anthropogenic Climate Change

GLOBES

See Cartography; Map Projections

GLOBALIZATION

At its most superficial level, globalization connotes the combination of global and local, two spatial terms of great importance to geographers. While the term apparently derives from a traditional Japanese word now used to describe the spatial niche marketing of commodities in the business literature, in more scholarly literature, globalization has come to mean something more complex: that globalizing processes only manifest
themselves in various ways in local contexts. That is, the global and the local are not separate spatial phenomena somehow interacting with each other, but rather, what is considered a “global” process is always already enacted variously in local settings. In this view, all cities in the world are global cities in that they all include globalizing economic, political, and cultural processes. How, to what extent, and to what possible future these globalizing processes manifest themselves, however, depends on local socioeconomic characteristics and trends.

This is a vision of spatial hybridity that sees the global and local as mutually formative. Unlike commentators who suggest that globalization is inevitably leading to a flatter, more homogeneous economic, political, and cultural world, glocalization scholars argue that, in fact, so-called globalizing processes are not only spread quite unevenly across the world, they also serve less to homogenize than to diversify this world as a result of hybrid glocal formations. The key is to observe each glocal context more closely to determine what globalization really entails. Cultural geographers thus consider globalization not as a convergence of global cultures but as the creation of new, heterogeneous, hybrid glocal cultures and individual identities. Political and economic geographers place more emphasis on the capacity of differential social power to create certain types of glocal hybridities as opposed to others as well as on the overall decline in the power of the nation-state to regulate global processes.

With respect to the latter, financial capital as well as some forms of productive capital clearly have transcended nation-state boundaries in terms of markets and investments. To conduct such business has necessitated the emergence of supranational governance institutions such as the World Trade Organization, the North American Free Trade Agreement, the European Union, the World Bank, and the International Monetary Fund, which necessarily reduces the sovereign decision-making powers of member states. At the same time, growing supranational economic activity has increased the competition among nations, regions, and localities to capture this activity, which is no longer regulated at the national level. To be successful at this process necessitates, in turn, the restructuring of internal social and economic governance to make it more conducive to the “free market” business practices of footloose supranational capital.

This idea is the source of the currently hegemonic neoliberal ideology of governance. Of interest is that the increasing deregulation of national spaces as well as the growing power of supranational governing institutions and transnational corporations have entailed the rising importance of governance at the subnational level of regions and metropolitan areas. As the free market nation-state relinquished its spatially “uncompetitive” role of equalizing development over the whole national territory, such subnational entities

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Indian youths queue at the opening of the first McDonald’s family restaurant in New Delhi, October 13, 1996. Officials of the giant U.S.-based chain announced that this is the only McDonald’s restaurant in the world with no beef on the menu, as most of the people of India do not eat beef.

**Source:** AP Photo/Ajit Kumar.
were increasingly left to their own devices in terms of successful economic development and social reproduction. Not surprisingly, subnational elites largely follow the neoliberal recipes for success adopted at the national level, thereby increasing place competition and social inequality at the subnational level. Viewed gloCALLY, this is a direct result of the growing discursive and real hegemony of national and subnational agents of increasingly powerful supranational processes. The weakening of nation-state regulation is thus consciously enacted by glocal agents and is not something forced by an inexorable, somehow external pressure of globalization.

The profound insight of the glocal approach is that by unreflectively thinking the global situation to be so, humans are acting to make it so. But, in fact, it is not actually so or, better, real globalization could be otherwise. This general glocal vision thus focuses on the ways in which not only this hegemonic discourse but also the emerging reality of globalization can be resisted. If globalization is really not a monolithic, homogenizing force but an uneven glocal phenomenon, then there are always openings for such resistance via both active hybridization and sociopolitical movement. In terms of the former, the focus is on the hybridization of individual and group identities as a result of the global movement of people and ideas, with the key concept of cultural transnationalism replacing internationalism. In terms of the latter, the focus is on how to negotiate differential power within and among the different spatial scales of productive activity and political governance that have emerged as a result of the weakening of nation-state regulation.

Viewed gloCALLy, then, nothing about “globalization” is necessary, but globalization is rather the result of conscious decisions made by some to the economic and social detriment of others. Globalizing processes are neither as strong as they seem nor should they be discussed as such. The political optimism of this approach is that once this is understood, one can imagine and enact a wholly different kind of globalization, less inequitable and more participatory. That this will entail a difficult discursive and real battle is certain. In fact, paying attention to the glocal makes it clear that some individuals and institutions have more power over space and place and other people than do others.

In geography, this is where the focus on globalization merges with the discussion of the significance of geographical scale in social relations. In short, paying attention to the glocal makes it clear that the currently hegemonic imagining and enaction of the “global” is but a specific social construction that can be deconstructed as a result of conscious re-imagining and the accompanying re-enaction.

Kevin Archer

See also Globalization; Hybrid Geographies; Locality; Neoliberalism; Regional Geography; Scale, Social Production of; Transnationalism

Further Readings


Reginald Golledge was a professor of geography and the director of the Research Unit on Spatial Cognition and Choice at the University of California, Santa Barbara (UCSB). His extensive body of work spanned more than 40 years of outstanding scholarship in the service of geography. As a senior faculty member at UCSB, he joined the geography department in 1977, only a few years after its inception. His efforts significantly contributed to the flourishing of geography at UCSB and helped establish one of the top geography departments in the United States.
Golledge was born in Australia in 1937. He received his BA (1959) and MA (1961) in geography from the University of New England in Australia and his PhD (1966) from the University of Iowa. During the following decades, he pursued a vast array of research projects. Golledge was highly regarded for his pioneering work in behavioral geography and disability geography. A noncomprehensive list of his research interests includes spatial decision making, migration, travel behavior and activity planning, spatial cognition, cognitive mapping, spatial abilities and spatial knowledge acquisition, wayfinding and navigation, visual impairment and other disabilities, and geography in K–12 (elementary and secondary) education.

Golledge wrote or edited 16 books, contributed to more than 100 book chapters, and was the author or coauthor of more than 100 academic papers. Just as his prolific publications speak of his devotion to geography and academia in general, an extensive number of honors and accolades have accompanied his distinguished career. Apart from holding an honorary PhD from Göteborg University in Sweden and an honorary LLD from Simon Fraser University in Canada, Golledge was named a Fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the Guggenheim Foundation. In addition, he received numerous awards, such as the Lifetime Award of the Association of American Geographers (AAG), the Gold Medal of the Institute of Australian Geographers, and the UCSB Award for Outstanding Graduate Mentor. Between 1998 and 2000, he first held the position of vice president of the AAG, followed by a term as president of the same organization. More recently, Golledge was the recipient of the Enhancing Diversity Award of the AAG in recognition of his work on geography and disability, actively striving to extend the notion of diversity to include those with disabilities. In early 2009, he was selected as the Annual Faculty Research Lecturer at UCSB, the highest honor given out by the UCSB Academic Senate.

Golledge earned respect and veneration within the discipline, not just due to his extraordinary academic record and scholarly work but also as a result of his lifelong commitment to his students. As an advisor, teacher, and mentor, he has had an impact on the lives and careers of numerous geographers.

Martin Swobodzinski

See also Behavioral Geography; Blindness and Geography; Disability, Geography of; Spatial Cognition; Wayfinding

Further Readings


Michael Frank Goodchild is a well-known British-American geographer and educator and an influential theoretician and pioneer in geographic information science (GIScience). As a professor of geography at the University of California, Santa Barbara (UCSB) since 1989, and codirector (1991–1997) and executive committee chair (1997– ) of the National Center for Geographic Information and Analysis (NCGIA), Goodchild has led the development of GIScience from its origins within the technical specialty of geographic information systems (GIS) to the status of a full-fledged academic field. GIScience studies the fundamental principles underlying the acquisition, handling, analysis, and dissemination of geographic information, addressing issues of representation, computation, visualization, and societal impact.

Apart from the vision that helped shape a nascent discipline, Goodchild’s notable contributions to geography include his persistent attention to the quality of geospatial data, uncertainty in their representation and interpretation, and resultant impacts on geospatial analyses. He has played a significant role in the global Digital Earth...
GOODE, J. PAUL

(1862–1932)

John Paul Goode played a key role in the development of 20th-century American cartography. Born in Minnesota in 1862, Goode received his bachelor’s degree from the University of
Minneapolis in 1889 and taught at the Minnesota Normal School in Moorhead from 1889 to 1898. In 1901, he completed his doctorate in economics at the University of Pennsylvania, and he subsequently played an important role in the cultivation of the nascent subdiscipline of economic geography, then called “commercial geography.” He taught geography at the University of Pennsylvania from 1903 to 1917 and at the University of Chicago (then a leading center of geography) from 1917 to 1928, where he taught a variety of courses, including cartography and graphics. Indeed, he is occasionally called the first true American academic cartographer; his students included Henry Leppard and Edward Espenshade. Goode was interested in advancing geographic education in a variety of respects and published widely on the topic. He also served as an “expert investigator” of the Chicago Harbor and for harbors in other cities.

Goode contributed to geography and related disciplines in several respects, including coediting the *Journal of Geography* from 1901 to 1904, helping organize and head the Geographical Society of Chicago, and serving as General Secretary of the American Association for the Advancement of Science in 1907–1908. He was a founding member of the Association of American Geographers in 1904 and served as its president in 1926–1927, giving as his presidential address a talk titled “The Map as a Record of Progress in Geography.”

Goode was well-known for his opposition to the widely used Mercator projection, particularly for its areal distortion at high latitudes, a problem that prompted him famously to label it the “evil Mercator.” In response, in 1916, he famously combined two other projections, the equal-area Homolographic (or Mollweide) and the Sinusoidal, which Goode noticed coincided at roughly 40°44′ latitude, to invent the Goode Interrupted Homolosine projection, a quasi-cylindrical view that depicted the globe in irregular joined parts, yielding a “peeled-orange” effect (Figure 1). By placing the interruptions over the oceans, the map could reveal continents relatively well; later, Goode made a similar map emphasizing global water space. The result effectively combined the Sinusoidal’s superior representation of equatorial regions with the Mollweide’s better view of polar areas. Unlike the Mercator, this approach preserved proportionate areal sizes, and it became widely popular for the representation of global thematic distributions. Goode was criticized at

![Figure 1](image-url) Goode’s Interrupted Homolosine projection. This famous projection preserved the relative sizes of places by revealing them in a series of disconnected parts.
times, however, for not positioning the United States in the center of the map, as was the custom at the time. He also developed the polar equal-area projection in 1928.

Goode also became widely known for initiating and editing *Goode’s School Atlas*, later renamed *Goode’s World Atlas*, which first appeared in 1922. Originally designed for use in schools, where it became a standard text in high schools and colleges, it also became enormously popular among the lay public. Over the following decades, often edited by his students, it reappeared in more than 21 editions to become one of the most commonly used atlases in the world, greatly accelerating the popularity of thematic cartography and powerfully influencing the geographic imagination of millions of people.

*Barney Warf*

See also Cartography; Cartography, History of; Map Projections

### Further Readings


**GOOGLE EARTH**

Google Earth is a virtual globe that is available for free through the Internet to anyone in the world who has an Internet connection and a computer with the minimum requirements. Google Earth is many things in one: a virtual globe, a 3D (three-dimensional) geobrowser, an interactive geospatial encyclopedia, a basic GIS (geographic information system), an advanced visualization technology, and a tool for teaching, learning, and entertainment (Figure 1).

Google Earth was originally developed by Keyhole Corporation, which Google purchased in October 2004. In early 2005, the basic version of Google Earth became available to the public. Google Earth enables exploration of the terabytes of images and information served by Google within the spatial context of Earth. In addition to Earth, the software includes a virtual rendering of the sky, a bathymetry of the ocean floor, and a virtual globe of the planet Mars.

The Google Earth virtual globe is covered with layers of satellite and aerial imagery of Earth displayed at various resolutions and scales. In certain areas, multiple images acquired on different dates can be viewed sequentially. Google Earth provides the user with numerous layers of information related to the location being viewed that can be optionally shown, such as Web links to articles, high-resolution and panoramic ground-based photography, 3D models of terrain and buildings (Figure 2), weather, traffic, road and street names, 360° photography of street views, points of interest, information related to organizations, and many other features that are continuously updated by Google and the Google Earth community.

In Google Earth, one can search for geographic features using Google’s search technology by simply entering the name of a geographic feature, an address, a place name, or a set of coordinates or by browsing with the mouse. The built-in DEM (digital elevation model) enables one to view the relief of mountains and valleys or dive below the surface of the ocean to observe the deep tranches and canyons (Figures 3 and 4). The user can fly over the terrain, pan, rotate, tilt, spin, or jump to another place on the globe.

Google Earth enables some basic functions of a GIS. Tools for measuring distances and areas and for creating lines and polygons that the user may save on his or her computer are all included. Users can also add their own information, which can be a place-mark, text, images, video, or links to other information on the Web. Users may also import GPS (global positioning system) data such as waypoints or tracks and create multiple layers of their own raster or vector data. Layers of
Figure 1  Google Earth with the borderlines in yellow and the layers of information on the left
Source: Google Earth.

Figure 2  The Capitol as a photorealistic 3D building
Source: Google Earth.
**Figure 3**  DEM (digital elevation model) of Half Dome in the Sierra Nevadas

*Source:* Google Earth.

**Figure 4**  Earth’s tallest mountain: Mauna Kea from the sea bottom shown in 3D

*Source:* Google Earth.
information may be saved to files using the KML (Keyhole Markup Language) and shared with other users using Google Earth as a posting board (Figure 5). With or without the use of KML, Google Earth can be an effective learning experience. Google Earth provides a way to visualize complex geographic information to make it more easily understood by the general public.

*Figure 5*  Real-time earthquakes layer made by the U.S. Geological Survey (USGS) and uploaded in KML to Google Earth

*Sources:* Google Earth and USGS.

Jean Gottmann was one of the premier urbanists of the 20th century. Born in the Ukraine, Gottmann was raised in France. After a traditional French education, he studied geography within the French regional tradition of Paul Vidal de la Blache. It is from this tradition that Gottmann started to develop his own ideas on the nature and meaning of geography, including the spatial theory that eventually led to his most famous work.

It was through the 1961 publication of *Megalopolis: The Urbanized Northeastern Seaboard of the United States* that Gottmann established himself as one of the most influential geographers of the 20th century. While he used the term *megalopolis* to refer specifically to the 600-mile-long metropolitan corridor between Boston, Massachusetts, and Washington, D.C., the term has been used to refer to any similar agglomeration of large

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**Further Readings**

*Google Earth: http://earth.google.com*
urban areas. The idea of a megalopolis is more than just a descriptive term for a system of functionally integrated cities; it is also a concept that embodies the notion of how and why space is organized. In *Megalopolis*, Gottmann’s view of space is presented as a dialectic between a constantly changing circulation of goods, information, and people and the attempt by individuals/groups to offset the tenuousness of change with the stability of a partitioned, iconographic territory. What *Megalopolis* represented was a new form of this ongoing dialectic away from the political nation-state to the economic urban region.

Two other aspects of *Megalopolis* make Gottmann’s contribution to the discipline of geography important. First, *Megalopolis* was published at the nexus of the transition in geography from the traditional descriptive, regional (idiographic) approach to the more “scientific” approach using deductive logic and the scientific method. Some argued that *Megalopolis* had too much description and not enough explanation. What Gottmann did in *Megalopolis* was bridge the gulf between the idiographic and nomothetic traditions in geography, which is why this work is still relevant today. Second, Gottmann’s observations concerning the formation of a megalopolis seem prescient. For example, in *Megalopolis*, he posits the idea that communications technology may, at some point, offset the “need” for businesses and populations to cluster. This idea continues to be one of the fundamental themes explored in both urban and economic geography. This is just one example of the remarkable work of the geographer Jean Gottmann.

*J. Matthew Shumway*

See also Exurbs; Metropolitan Area; Suburbs and Suburbanization; Urban Geography; Urban Hierarchy; Urbanization; Urban Sprawl

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One of the discipline’s most creative and diverse thinkers, Peter R. Gould wrote about a wide variety of topics in geography, ranging from transportation to AIDS to television to critiques of Marxism. During his career, he authored 20 books and monographs and 170 journal articles. Fluent in French, he also published in that language.

Born and raised in England, he was evacuated to the United States during World War II. Returning to England afterward, he attended the Nautical College, graduating in 1951. Immediately thereafter, he served with the British military against communist guerrillas in Malaysia. In 1956, he graduated from Colgate University, and he went on to do graduate work at Northwestern University, completing his PhD in 1960. Initially an Africanist, he journeyed widely and conducted fieldwork in that continent before assuming a faculty position at Syracuse University. In 1963, he moved to the Pennsylvania State University (Penn State), where he remained for the next 35 years, taking sabbaticals in a variety of countries. He retired in 1998 and died of cancer shortly thereafter.

Gould was eclectic in his research interests. He maintained a fascination with the structure of cognition, and his early work included the study of mental maps and residential preference surfaces. He was also deeply interested in issues of geographic philosophy. Although he was certainly not an empiricist, he exhibited a deep distrust of armchair theorizing and rigidly held views that led inexorably to predetermined theoretical conclusions, a fault he often attributed to Marxism. He pursued Heideggerian phenomenology as a means of comprehending human experience. He could be polemical, and he challenged feminist geographers and postmodernists in ways that were often disconcerting and earned him considerable criticism. Gould had an abiding love for mathematics, which he deployed in novel ways, and helped propel the quantitative revolution. Among his favored techniques were linear programming, game theory, entropy maximization, and eigenvalues. He was an enthusiastic advocate of Q-analysis, a sophisticated combinatorial technique derived from set theory, as a means of...
uncovering the deep structure of empirical reality, and he applied this method to different topics, including the international diffusion of television shows. He wrote about the diffusion of AIDS, employing novel forms of cartography to explore its temporal and spatial dimensions. Gould also authored a volume on the nuclear accident at Chernobyl and the wide cloud of radioactive material it unleashed.

Finally, Gould was a highly committed and innovative teacher greatly concerned about issues of pedagogy. *Spatial Organization: The Geographer’s View of the World*, coauthored with Ronald Abler and John Adams, was pioneering in integrating diverse strains of the discipline for undergraduate students. Drawing on a lifetime of experience, his volumes *Geographer at Work* and *Becoming a Geographer* earned him great acclaim. On his death, Penn State created the Peter Gould Geo-Center for the promulgation of geographic thought and teaching.

*Barney Warf*

**Further Readings**


**Governance**

The idea of governance has traditionally been understood as the pursuit of the activities of government or the actions taken by political leaders and government bureaucrats for the benefit of people. During the late 20th century, the term *governance* began to be used more broadly by geographers, political scientists, and other social scientists to refer to activities that not only included government actors and institutions but also notably extended beyond government. The wider actors and institutions involved include civil society, such as nongovernmental organizations, as well as, increasingly, corporate interests. Individual citizens have also been encouraged to actively participate in community-based planning processes. The notion of “good governance” in social science parlance signifies the inclusion of the multiple stakeholders who share a common concern, albeit often from conflicting perspectives, toward finding a workable and equitable way forward to manage that shared concern. This idea has become an important metanarrative for policy analysis in geography and political science. Conceptually, the idea of good governance can be applied at various scales and to a range of different concerns. This entry explores the ideas of environmental governance, local governance, global governance, and multilevel governance.

**Environmental Governance**

The term *environmental governance* signifies the pursuit of governance with reference to issues that broadly pertain to sustainability issues. The
concept of environmental governance can occur at the global scale, as with concern about climate change; at the regional scale, as in transboundary watershed management; and at the local scale, as in decision making on recycling initiatives, landfills, or other local environmental issues. The appropriate scale for addressing environmental governance concerns is often influenced by the biophysical limits of the resource in question, with the stakeholders who are then involved defined by their interest in the resource in question. For example, while good governance of water is a concern shared by many people, the practical challenges of managing water vary greatly in different locations based on factors such as water availability, population, climate, and biogeography. Water’s biophysical boundary is the watershed, which often complicates establishing effective governance institutions because the biophysical boundary often does not correspond to political boundaries. Hence, good governance at the watershed scale could include planners from multiple government jurisdictions and the range of often conflicting nongovernmental interests with competing demands for limited water.

For shared environmental resources, an underlying concern is to devise workable and equitable solutions that encompass both intergenerational and intragenerational equity. Intergenerational equity is particularly challenging because, while future generations have a stake in the protection of resources for the future, they (as well as the resources, wildlife or a habitat) cannot participate on their own behalf and depend on the advocacy of stakeholders such as environmental nongovernmental organizations. Part of the rationale for widening participation through environmental governance is that politicians and bureaucrats lack the mandate to take into account the needs of future generations or of nature itself (often popularly explained as “people vote and bunnies don’t”) and that, through governance with involvement that extends beyond government, these considerations can be better integrated into decision making.

The institutions of a governance process can manifest in different forms depending on the nature of the resource and the controversy surrounding a given issue. One form is the idea of managing common pool resources through collective action, but other institutional structures can also be deployed. While the institutions and the form of the process may vary, the principles of good governance require that wider stakeholders, through some institutional structure, either formal or informal, have an opportunity to participate in decision making.

### Different Scales of Governance

As mentioned above, governance can occur on different scales. The term *local governance* describes activities involving shared concerns at a local level and conceptually and practically encourages the involvement of the individual in shared community concerns. This process can include formal roles for individual citizens, such as sitting on decision-making committees, or more informal roles. The idea of governance is linked to encouraging individual and collective citizenship in the pursuit of common goals such as safer or cleaner communities.

At the global scale, the idea of good governance seeks to provide an organizing framework for issues that extend beyond the limitations of national boundaries, such as poverty, international trade, and climate change. The United Nations and the International Monetary Fund are examples of formal institutions that increasingly seek involvement beyond government. One current example of an attempt at global governance is the agreement on the Millennium Development Goals.

Some issues may lead to multilevel governance, which links initiatives across scales to enhance governance solutions. One example is the Kyoto Protocol, where many nations agreed to national targets for emissions reductions; when the United States did not enter this global-scale agreement, many mayors of major U.S. cities (i.e., an ad hoc collective action of local governments) made commitments to targets for their individual cities.

*Mary Dengler*

See also Civil Society; Common Property Resource Management; Community-Based Environmental Planning; Environmental Law; Environmental Management; Environmental Planning; Governmentality and Conservation; Multistakeholder Participation;
Governmentality and conservation is a developing area of scholarship that addresses the alignment of nature conservation initiatives with political, economic, and social change. It draws heavily on the French philosopher Michel Foucault’s analytics of government to describe and critique some of the shifts occurring in the relationships between government, corporate, and community actors concerning nature conservation, emphasizing the roles played by both individual and collective subjects within broader networks of power relations that operate on multiple geographical scales.

From his studies of government transformations in Europe between the 15th and 18th centuries, Foucault observed that new political rationalizations emerged in particular sites at particular historical moments, underpinned by coherent systems of thought. While beginning as new sets of ideas and systems of thought, these practices eventually became linked to a range of new regulatory practices. Although Foucault himself never applied these ideas to environmental governance or nature conservation, there has been particular interest among geographers, political ecologists, and others in the social sciences in drawing on ideas of “governmentality” for understanding new approaches to environmental management, the management of natural resources, and human-environment relations more generally. These approaches are linked to shifts in the role of the state, but they also operate at a more epistemological level.

While the literature on governmentality and conservation has largely developed since the 1990s, it has strong connections with the more established literature about the role of the commons versus individual property rights in the management of natural resources. While, on the one hand, contemporary environmental governance initiatives seek to create new forms of individual property rights in nature, on the other hand, many environmental programs emphasize collective responsibilities for good environmental conduct in the common interest.

Further Readings


to describe this phenomenon. For example, concerns about rising levels of atmospheric carbon dioxide and their implications for global climate change give rise to new sets of assumptions about the responsibility of individual householders to reduce energy use in the home.

**Governmentality**

The term *governmentality* refers to a broad range of tactics and strategies of government that includes the structures and procedures of institutions as well as the technical means of implementing these procedures. These are concerned with what Foucault termed “the conduct of conduct,” or the establishment and oversight of norms of social practice and behavioral conduct. For example, these might include the definition of new forms of property, such as carbon emission permits or quantum measures of biodiversity, along with the establishment of new market mechanisms for trading in them. It might also include the forms and procedures that government agencies require community organizations to complete when applying for funding grants. A key contribution of Foucault’s analytics of government is its central concern with the exercise of power through such procedures and practices.

Measurement and statistics are key tools for the representation of human populations, specific aspects of nature, and the humanity-nature relationship more generally. For example, statistics about population growth, climate change, and biodiversity loss have become key to the representation of the humanity-nature relationship. They form a specific technology of governance, referred to as biopolitics, and are used by different kinds of organizations to frame discourse on sustainable development and the limits to human existence. This discourse conveys specific knowledge and understanding of the status of environmental entities such as the global atmosphere that provides the rationale and imperative for new regulatory regimes.

**Space and Scale**

Concepts of space and scale are critical to the analytics of environmental governance, and geographers have played an important role in demonstrating how they are deployed in a wide range of governance contexts. Specific environmental entities, ranging from the genetic makeup of organisms to entire river basins or the global atmosphere, become referents for environmental governance initiatives. As such, environmental entities that exist at quite different geographical scales are construed as “governable spaces” and form the locus for new forms of responsibility and ethics expressed in standards or norms of behavior. There are strong links between these ideas of governable spaces, and recent scholarship in geography emphasizes the need to think of place in terms of its ongoing production through different sets of social relations that bring with them different dynamics of power. While it is clear that the transformation of nature is associated with social transformation, geographers such as Eric Swyngedouw and David Harvey highlight the complexity of the scalar dimensions within each form of transformation and argue the need for caution in drawing connections between them.

*Ruth Lane*

See also Common Property Resource Management; Environmental Ethics; Environmental Law; Environmental Management; Environmental Planning; Neoliberal Environmental Policy; Neoliberalism; Place; Political Ecology; Production of Space; Regional Governance; Scale, Social Production of

**Further Readings**


**Gravity Model**

The gravity model is a popular mathematical model used to predict the interaction between two or more places. In geography, it has been used to simulate a variety of flow patterns, such as traffic and mail flows, telephone calls, and migration. Essentially, the gravity model can be used to account for any interaction or flow that is expected to move from one place to another. This idea has generated many mathematical manipulations of the model.

The original gravity model is based on Newton’s law of gravitation, expressed as

$$G_{ij} = \frac{G M_i M_j}{d_{ij}^2},$$

where $G_{ij}$ is the gravitational bond between objects $i$ and $j$, $G$ is the gravitational constant, $M_i$ and $M_j$ are measures of the attractiveness of masses $i$ and $j$, and $d_{ij}^2$ is the square of the distance between objects $i$ and $j$. The theoretical principle of the gravity model is twofold: (1) the degree of interaction is directly proportional to the size of the masses and (2) the degree of interaction is indirectly proportional to the distance that separates them. E. G. Ravenstein later applied these principles and the gravity model concept to the social sciences with a study of migration patterns during the 19th century.

Generally, three types of gravity model have evolved since Ravenstein’s formulation: (1) origin-specific, (2) destination-specific, and (3) network or potential models. The basic gravity model formulation is the foundation of origin- and destination-specific models. It takes the following form:

$$I_{ij} = k \frac{P_i P_j}{d_{ij}^b},$$

where $I_{ij}$ is the interaction between places $i$ and $j$, $k$ is a constant, $P_i$ and $P_j$ are measures of the size of places $i$ and $j$ (e.g., populations), $d_{ij}$ is the distance between places $i$ and $j$, and $b$ is the friction of distance. Larger values of $b$ indicate that the interaction between $i$ and $j$ declines more rapidly with increased distance. Commonly, origin-specific models are used to predict flows from one place of origin to several destinations. With destination-specific models, flows are predicted from several origins to one destination. The gravity model was later reformulated to account for a network of interactions between places. These are known as potential models, expressed as

$$V_i = \sum \left( \frac{M_j}{d_{ij}} \right),$$

where $V_i$ is the population potential of place $i$, $M_j$ is the population of $j$, and $d_{ij}$ is the distance that separates place $i$ and $j$. Results of the potential model show the position of each place relative to all other places. Often, the results are illustrated spatially with a potential surface map.

Most criticism of the gravity model has concerned its use as a predictive tool. Some note that the model is not based on observation and therefore cannot be substantiated scientifically. Others believe that the model is biased toward existing spatial patterns and that this will perpetuate the status quo.

Todd Sink

See also GIS in Transportation; Migration; Mobility; Spatial Interaction Models; Transportation Geography

**Further Readings**


**Great American Exchange**

The Great American or Columbian Exchange refers to the transmission of agricultural crops, domesticated livestock, technology, and disease between the Afro-Eurasian region and the Americas that occurred after the voyages of Christopher Columbus to the New World reestablished
Contact between the two continental systems and their respective populations (Table 1). The most prominent impacts were in the areas of disease transmission and new agricultural crops. These transfers were by no means equivalent. The New World, with its relatively lower population density, did not acquire immunity to the diseases imported from Europe, Asia, and Africa. Native American resistance to malaria, measles, smallpox, tetanus, and typhus was nonexistent, and this resulted in an estimated loss of up to 70% of the population of Middle and Southern America, while the populations in the Americas overall are estimated to have decreased between 50% and 70% following contact. Europeans were introduced to a new form of syphilis in the course of opening up the New World to commerce and settlement.

The exchange of crops and livestock were, however, more balanced. Europe gained tobacco, maize, beans, peanuts, several kinds of potatoes, manioc (which has since become a staple in parts of Africa), squashes, pumpkins, chocolate, papayas, guavas, avocados, pineapples, tomatoes, chili peppers, and cayenne. The Americas received chickens, cattle, goats, pigs, sheep, horses, wheat, grapes, bananas, rice, sugar, and honeybees. However, the impacts of crop exchange were also differential. For Americans, the European crops were somewhat less efficient users of arable land. Their origin in higher latitudes meant that they were adapted to a shorter growing season than that of the tropics, hence they could not be harvested as often as native crop species. In addition, the sudden release of more grazers on natural crops led to famine. In the years that followed, the impact of American silver and gold on the policies of Spain and the general rush to colonization cannot be understated either. In Asia, the impacts of New World crops were remarkable. In China, for example, more than a third of the crops currently grown are of American origin.

Finally, there was an exchange of ideas and people. Some scholars contend that notions of democracy in European societies were reawakened and strengthened by the discovery of relatively egalitarian Native American societies and the corresponding development of Rousseau’s “noble savage.” However, the stronger impact was by far the imposition of the plantation model of society on Southern and Central America. The mass movement of millions of Africans into the Americas forever changed the political landscape. The notion of racially based hierarchies of power and wealth eventually prevailed over indigenous power structures based on religion, wealth, and lineage. The Columbian exchange also forced the European colonizers, especially the Spanish and Portuguese, to modify their religiously based mandates for colonization and refine the notion of a “mission to civilize the world,” which would later be spread to African and Asian colonies.

Edward Rice

See also Biodiversity; Biogeography; Exotic Species; Human-Induced Invasion of Species

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GREENBELTS

A greenbelt is a section of land deliberately left undeveloped as either forest or agricultural space, often near urban centers, generally for purposes of environmental conservation.

Historical Formation of Greenbelts

In 1829, an etching by the artist George Cruikshank showed London literally “going out of town,” with development spewing onto the countryside and threatening the tranquility of pastoral England. Britain’s Industrial Revolution had prompted unprecedented urban growth, triggering two areas of critical concern for future generations of planners: (1) the well-being of urban centers and (2) the relationship between these centers and their rural hinterlands. In the preindustrial era, many significant settlements had been contained by fortification. Across Europe and Asia, towns and cities were frequently enveloped by man-made or natural barriers—walls, the sea, rivers, or mountains—by anything, in fact, that afforded some protection from the incursion of rival powers. The nearby countryside provided sustenance for the urban population, such as it was, in a largely agrarian world dominated by an urban nobility and populated by a rural peasantry.

But industrialization and the subsequent urbanization changed the world forever. Britain—the first industrial nation—was also one of the first to take note of the environmental and aesthetic consequences of this change. Cruikshank’s imagery was one of a number of comments—artistic, poetic, and political—to gradually raise the profile of this issue in the public mind. Threats to the countryside in 19th-century Britain were taken seriously. Conditions in the major urban centers were often so dire, so unsanitary, that adjacent rural areas were justifiably concerned about urbanization, though they were powerless to prevent it.

By the end of the 19th century, a few visionaries—Ebenezer Howard being the most notable—had become convinced of the need to reconnect urban populations to the fresh air and other health benefits of the open, green countryside. For Howard, this could be achieved through the creation of Garden Cities: planned centers covering areas of 1,000 acres and with populations of no more than 32,000 situated within at least 5,000 acres of agricultural land that would be protected from further encroachment. In the absence of fortification, cities still needed to be contained—fortified against their own expansion rather than the actions of foreign armies.

At various points throughout the 20th century, different countries reached this same conclusion. But because of its 19th-century experiences, and the lobbying of a number of key individuals (Howard being an early trailblazer), Britain led the way in the development of urban containment tools as part of a broader rural development intolerance, aiming to protect the interests of farming and what became regarded as the rural idyll. Two prominent figures in the evolution of British town planning—Patrick Abercrombie and Raymond Unwin—played crucial roles in promoting the idea of statutory greenbelts. In 1926, Abercrombie highlighted the danger posed by urban decentralization, arguing for a concerted effort to preserve rural England. His writing inspired the creation of the Council for the Preservation of Rural England (CPRE), which campaigned for stricter rural development controls. Planning legislation in the 1930s took up this theme, introducing new restrictions on “ribbon” development (residential development along roads and railway lines extending from urban centers). But it was Unwin who, in 1933, proposed the creation of a “green girdle” around London primarily for recreational purposes. Two years later, the municipal authorities were supporting Unwin’s idea of a “London Greenbelt”; but it was not until 1938 that Parliament legislated for its creation. This prewar greenbelt could only be realized through the purchasing of privately owned open spaces on the edge of the city. Only through a nationalization of development rights—still 9 yrs. (years) away—would it be possible for planning authorities to draw lines on maps and tell landowners and prospective developers that further land use change would be effectively prohibited.

The development of this urban containment approach gained real momentum after the war. Abercrombie incorporated a greenbelt into his 1944 Greater London Plan, and 3 yrs. later, the
Town and Country Planning Act of 1947 created a system of comprehensive land use control, built on a nationalization of development rights and the transfer of planning power to local councils. The stage was set for a comprehensive system of greenbelts, and this duly arrived in 1955, with the British government urging local authorities to formally designate clearly defined greenbelts, where these were considered necessary and appropriate. According to the Ministry for Housing and Local Government, these were to have the objective of "checking the unrestricted sprawl of the built-up areas, and of safeguarding the surrounding countryside against further encroachment."

Contemporary Greenbelts

The evolution of this approach to urban containment in Britain is the first chapter in the story of the greenbelt. It has since been lauded by the CPRE as "planning's most celebrated achievement." The regularity with which other countries have duplicated the British approach—at least in name—is held up as evidence that Britain "got it right" and that this form of growth management is the best way to serve the interests of cities—concentrating urban regeneration efforts within the existing urban footprint while checking sprawl and protecting the countryside from encroachment. Numerous countries have imported the greenbelt idea. In North America, both the United States and Canada have adopted this containment approach as a means of preserving agricultural land and setting urban growth boundaries.

In Canada, a complete greenbelt encircles the city of Ottawa, while a horseshoe-shaped greenbelt has been designated around the Greater Toronto Area and the Niagara Peninsula, aiming to protect this environmentally sensitive area from future sprawl.

The development of greenbelts in the United States has a particularly interesting and varied history. In a move reminiscent of—and inspired by—the British Garden Cities movement, a number of "green towns" were planned and built as part of President Franklin D. Roosevelt's New Deal. The first of these towns was the City of Greenbelt, Maryland, built on the edge of Washington, D.C., in 1937 and designed as a cooperative, walkable, garden suburb that would be a model of modern town planning in the United States. Many other such towns were planned, but only two were built: Greenhills on the fringe of Cincinnati, Ohio, and Greendale, outside Milwaukee, Wisconsin. The government-sponsored green towns inspired a number of private projects across the country, but like the City of Greenbelt, many have since lost their original cohesiveness and character, often as a consequence of freeway development and associated sprawl. General containment tools—which might have provided some protection to these exemplars of greener living—arrived too late to save the Green Towns, while, in comparison, the two Garden Cities developed in the United Kingdom have been afforded some protection by London's greenbelt and by exclusive environmental safeguards.

Although not strictly greenbelts, many U.S. states have used urban growth boundaries as a means of controlling the spread of high-density development with a defined urban edge. Oregon, Washington, and Tennessee require cities to define boundaries beyond which only lower-density development of specified types will be permitted. Recent analyses of the urban growth boundary approach have highlighted the effect that this zoning has on land prices and on residential property values, arguing that this form of growth management—like greenbelts elsewhere—serves the interests of existing property owners and restricts access to housing among new buyers.

Similar tools have been used to manage the outward spread of cities in other locations around the world. A notable and much studied example is that of restricted development zoning around Seoul, South Korea. Although this is sometimes referred to as a greenbelt, it has far more in common with the U.S. urban growth boundary approach. Set within a system of zonal planning in which higher-tier strategic authorities claim jurisdiction over the policies affecting local areas (as opposed to the system of local political "discretion" that operates in the United Kingdom), restricted development zoning is a means of reducing development densities and giving South Korea's overheating capital region an identifiable urban boundary. The hope has been that growth in Seoul will not merely be contained but will be diverted.
to other centers. This is yet to happen: Urban pollution and traffic congestion remain weaknesses of Korea’s economic miracle but have now been joined by the added problem of low-quality development leapfrogging Seoul’s greenbelt.

It is perhaps fitting that the United Kingdom—the earliest greenbelt pioneer—is now the setting for an intense debate on the future direction of containment policy. The creation of a comprehensive planning system in 1947 provided the backdrop for the development of the greenbelt; comprehensive reform of that system in the 2000s provides another backdrop, but this time for calls to rethink the role and purpose of the greenbelt (Figure 1). The last time the policy was most recently rewritten, in 2001, it essentially retained its postwar focus: checking sprawl, serving regeneration efforts, preventing urban coalescence, preserving the settings of historic towns, and safeguarding the countryside. Beneath this list of purposes sits another list of ways in which greenbelt land might be used: for general access, sport, and recreation; for farming and forestry; and as a resource that can be beautified, serve conservation interests, and undergo improvement where there is evidence of postindustrial scarring.

Since the 1990s, both the central purpose of greenbelts, and how their use is promoted (for recreation, conservation, and enhancement), have been continually questioned. Representatives of the planning community—the professional bodies—have argued that it is out of step with reform of the wider system and a barrier to providing the growth and infrastructure that the United Kingdom now needs and that general planning reform is designed to deliver. It has been called an inert green blanket, smothering the countryside and preventing the diversification of rural economies that are today struggling to find a postagricultural future. A central criticism is that greenbelts should become a positive force in leading change within peri-urban environments and not simply an inflexible barrier to the necessary transformation of the urban fringe.

Criticisms of the greenbelt’s purpose are well rehearsed: Tightly drawn boundaries promote town cramming rather than regeneration; pressure builds and can only be released through leapfrogging over the greenbelt to distant locations where car-dependent developments, isolated from existing infrastructure and inherently unsustainable, are promoted. It is argued that a logical alternative would be to use the planning system to support sustainable urban extensions, keyed into existing infrastructure, and to transform the greenbelt into a framework for projects that exemplify the highest standards in green, zero-carbon development.

The idea that the greenbelt could become a framework for promoting something positive is a more recent aspect of the debate. A comprehensive review of land use planning (paving the way for further reforms) recently concluded that despite their published objectives, greenbelts are understood, primarily, to be control tools. Far less consideration is given to the delivery of valued environmental and social objectives. The label greenbelt is somewhat of a misnomer: Land under this designation is often somewhere on a continuum between gray and green, frequently subject to postindustrial scarring. In the United Kingdom—and also in the United States—there are calls to make the greenbelt more proactively green, delivering a program of social and environmental benefits within areas of urban fringe (returning to the ambitions of Howard’s Garden Cities and Roosevelt’s Green Towns) while retaining its role in restricting unchecked sprawl, though sometimes by permitting the planned release of land for residential and associated development.

Many countries have taken note of the development of greenbelt policy in the United Kingdom. While the tool is not always well understood, there is some hope that it will evolve to face the challenges of the century ahead. Cities around the world share a concern over development sprawl and unsustainable, sporadic urban growth. Greenbelt is likely to survive, in one form or another, with shared concerns prompting shared efforts to evolve containment into a growth management approach that can bring positive benefits.

Nick Gallent

See also Green Design and Development; Parks and Reserves; Smart Growth; Urban Gardens; Urban Green Space; Urban Sprawl
Figure 1  Britain’s greenbelts in 2008

Green buildings are structures that are designed to have a reduced environmental impact compared with standard construction methods and materials. When the concept was introduced in the 1970s because of concerns over rising energy use and environmental pollution, green building was largely carried out by people constructing their own homes. Since 2000, however, the growing concern over global warming, water resources, and sustainability has led to a movement that is influencing development in the public and private sectors across the world, from houses to skyscrapers. The standards that have been developed to certify green buildings are part of the general 21st-century shift away from government regulation and toward voluntary, performance-based standards. Because of the focus on economic and environmental but not social issues, green buildings do not generally fit the traditional definition of sustainability; instead, they are sometimes called high-performance buildings.

According to the nonprofit U.S. Green Building Council (USGBC), buildings within the United States produce nearly 40% of global carbon dioxide emissions and 30% of waste output, while consuming 7% of the world’s electricity, 40% of its raw materials, and 14% of the potable water. In most cases, there is relatively little that building inhabitants can do to reduce these figures once the structure is in place. The responsibility for producing more environmentally friendly buildings is therefore placed on the shoulders of those who design and construct them. At the same time, there is tremendous potential for reducing resource consumption and waste production by better building designs and construction practices.

There are three general approaches to greening buildings. The first is to rely on existing vernacular building practices and materials, such as adobe structures in desert climates to take advantage of large temperature fluctuations or raised floors in hot and humid climates to allow for airflow. The second approach is high-tech, relying on new materials and processes to reduce resource use and minimize waste. The third is biomimicry, imitating natural processes and using natural materials. Each has different implications in terms of capital requirements, marketability, and effectiveness. The technological approach dominates the industry at the present time, as seen by the term high-performance buildings.

There is no single definition of what makes a building green. The Leadership in Energy and Environmental Design (LEED) standards of the USGBC considers six dimensions: (1) sustainable sites, (2) water efficiency, (3) energy and atmosphere, (4) materials and resources, (5) indoor environmental quality, and (6) design innovation. The idea is to go beyond simply using less water or energy, by considering how multiple components of a building’s design work together in a mini-ecosystem that consists of the site and its relationship to the surrounding networks of transportation, wildlife habitat, and urban space; the indoor environment, including emissions from paint and carpet; and the sources and sinks for the materials that go into the building and the wastes that come out. The complexity of a green building means that architects, engineers, and construction managers have to work closely together to achieve the goals of the project.
Most green building certification systems are point based, designed to be flexible and allow project owners to decide the level of certification and which points or credits they want to earn to achieve that level; this flexibility is one reason why green building standards have been widely embraced. Various categories of certification focus on different building types such as schools, hospitals, and homes to broaden the range of categories and incorporate uses such as laboratories that may have special energy or water needs. At the same time, many jurisdictions from local to national levels are implementing requirements that certain types of development must achieve a set level of certification. Some jurisdictions use incentives such as expedited permitting or tax breaks rather than requirements, creating a patchwork of regulation from one place to the next.

U.S. studies have found that while the perception exists that green buildings are considerably more expensive than conventional structures, data on finished buildings indicate an increased cost of about 5%, which is usually earned back within a couple of years through increased energy savings. Additionally, employees have been shown to have fewer sick days and schoolchildren to have higher test scores when they work and learn inside certified green buildings. Other studies have found that green buildings under operation not only use less energy, as predicted, but also bring in higher rental value.

Globally, programs such as the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, Green Star in New Zealand and Australia, and the Green Globes in North America serve a similar function to the USGBC’s LEED. The LEED standards have been adopted in over 40 countries,
including Brazil, China, and India, while BREEAM International has been employed in countries across Europe and Asia. The major differences between the systems are in terms of how certification is approved (onsite inspection for BREEAM, documentation for LEED) and in percentage reductions from a baseline (LEED) as compared with quantitative targets (BREEAM).

Green building is increasingly tied to green-collar jobs in some locations: manufacturing and installing materials such as wind turbines, low-emissions paint, and photovoltaic panels. Particularly within the United States, concern over the outsourcing of manufacturing and the concomitant loss of jobs for skilled laborers is part of the green-collar job movement. Green building programs contribute to this movement by, for example, designating credits for using materials produced within 500 miles of the building site, which is meant to encourage economic development as much as environmental responsibility.

Criticisms of green building include its failure to incorporate life-cycle analysis, although that is changing; higher costs, although that is under debate, as described above; and epitomizing ecological modernization by continuing business as usual with a green façade. Nevertheless, green buildings are gaining a greater share of the market worldwide and are at least in a small way reducing the ecological impact of the built environment.

Julie Cidell

See also Architecture and Geography; Built Environment; Environmental Impacts of Cities; Green Design and Development; Smart Growth

Further Readings

U.S. Green Building Council: www.usgbc.org
1960s and 1970s, saw growing attention to the level of environmental resource extraction and the impacts of human activities on the environment. Geographers were heavily involved in the formation of means to assess levels of resource use and environmental impacts and in consideration of the meaning of terms such as resource, environment, and nature. Other professionals, including engineers, planners, economists, and architects, as well as environmental activists, began to consider the environmental resource and impact dimensions of object and building design and construction.

In 1973, for instance, the economist Ernst Schumacher published Small Is Beautiful, a book that criticized existing models of economic development for fostering reliance on Western technology and thereby heightening dependency relationships. Schumacher argued that Western technologies were often highly inappropriate for many poor/developing/underdeveloped countries, both socioeconomically and environmentally. Schumacher advocated the development of more appropriate forms of technology, which he described as being intermediate technologies, lying somewhere between the technologies of the developing and the developed world in terms of capital and labor intensities. Schumacher sought to put his ideas into practice through the Intermediate Technology Development Group (now Practical Action), and they were also influential within organizations such as the Centre for Alternative Technology at Machynlleth, Wales. Schumacher’s ideas were picked up by designers such as Victor Papanek and Gui Bonsiepe, who were influential in the “design for need” movement of the 1960s and 1970s. His ideas were also influential in development studies, where they were connected to, and critiqued within, debates over the meaning of development.

**Sustainable Development and Green Capitalist Design**

Differential understandings of development were equally significant to the concept of sustainable development that emerged strongly after the 1987 report of the World Commission on Environment and Development, Our Common Future (or the Brundtland Report, as it came to be more commonly known). The Brundtland definition of sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs was compatible with technocentrism in that it did not provide any direct challenge to conceptions of development as economic growth. Indeed, Our Common Future can be seen to have espoused an ecological modernization perspective in that it portrayed economic growth as a mechanism for improving environmental protection, as well as proposing that environmental resources were essential for continuing economic growth.

While the Brundtland conception of sustainable development was criticized, by the 1990s it had become widely adopted in international, national, and local policy making. This was particularly so when the concept was conjoined with growing concerns over global environmental changes such as atmospheric ozone depletion and climate change, along with localized concerns over pollutants. Technological development was a key element in the espousal of “green capitalism” in the late 1980s and early 1990s, whereby it was argued that new “environmentally friendly” products were being created, often by businesses that were otherwise seen as producers of considerable environmental pollution, such as petrochemical companies, power producers, and car manufacturers.

Examples of new environmentally friendly products cited as illustrations of green capitalism include low-energy light bulbs, biodegradable oils, nonchlorofluorocarbon (CFC) propellants for aerosols, lightweight and low-noise aero-engines, and more fuel-efficient and less polluting car engines. In some cases, the environmental design dimensions of products only extended to labeling and marketing, as with the case of “environmentally friendly, phosphate-free” dishwashing liquids, which emerged in the 1990s, even though phosphates were not generally constituents of ordinary dishwashing liquids. However, even product designs that have clear environmental benefits, such as low-energy light bulbs and solar energy/heating panels, do not necessarily qualify as being environmentally friendly, given that the products and processes used to manufacture, package, market, and distribute them consume energy and resources as well as generating
waste materials that can become pollutants. Concepts such as carbon miles, environmental and ecological footprints, and cradle-to-grave product life cycles emerged as ways of assessing the multiplicity of impacts a single product can have on the environment.

These techniques have been quite widely employed by environmental pressure groups and consumers, plus incorporated into product design practices, although their use has often been viewed as a matter of individual preference and environmental consciousness, coupled with the attractiveness of certifications of environmental standards, such as the USDA Organic Seal, to green consumers. However, with growing governmental concern over issues such as global warming and energy security, more regulative approaches have been adopted that could be viewed as indicative of an institutionalization of environmental concern such that it constitutes a policy regime, mode of social regulation, or mode of governmentality.

**Low-Carbon Design and Eco-Housing Development**

Governmental regulation and promotion, in many cases associated with meeting requirements to reduce greenhouse gas emissions, have fostered significant developments in product design in many areas, much of it oriented toward the creation of low- or zero-carbon energy products. For instance, there has been a significant increase in investment in carbon-free and renewable energy supplies, with a range of new technologies being developed and improved, including wind turbines, photovoltaic panels, ground source heat pumps, and biofuels, as well as developments in emissions reduction and energy conservation.

Many of these technologies have been employed in connection with housing, where there have been numerous developments not only in energy production and conservation but also with respect to resource use and waste production and disposal. Some of these technological developments employ materials and production techniques that were previously in use but had come to be seen as obsolete in modernist production, as with the use of earth and straw cob or natural ventilation. Other technologies, such as so-called smart homes, adopt an ecological modernist approach centered on the use of newly emergent electronic, computing, and communication technologies to monitor and adjust energy and resource use.

Figures on the number of eco-house developments are difficult to obtain, but it has been suggested that they form important “green niches” where new technologies, designs, and social practices are assembled and tried out by small groups of committed practitioners in bespoke developments, whose learning experiences and practical successes can then be disseminated more widely. A series of model or exemplary developments have long and widely been identified, such as the Beddington Zero Emission Development (BedZED) in London; the B001 development in Malmo, Sweden; Ecolonia in Alphen aan den Rijn, the Netherlands; the Schlierberg estate in Freiberg, Germany; Drake Landing Solar Community in Alberta, Canada; and Crystal Waters, in Brisbane, Australia.

These initial efforts were subsequently recognized and emulated in some degree by other individuals, businesses, and governmental agencies. Illustration of such diffusion of green design includes the movement of double-glazing installation firms into solar energy/heating provision, as well as the construction of eco-housing by mass house-building companies. Another form of diffusion from niche developments has been the emergence of planned eco-neighborhoods, or sustainable communities, that constitute variously scaled collections of eco-housing, often in combination with production, consumption, and recreational facilities. Such developments range from groupings of a few houses and associated buildings, through eco-villages such as Findhorn in Scotland, which has around 55 buildings, to “eco-towns,” which in the case of the United Kingdom include prospective settlements of 5,000 to 20,000 homes.

The increasing scale of developments has at least two significant implications. First, it has involved a widening of design focus beyond buildings to encompass wider activity spaces and travel patterns. Concepts such as sustainable neighborhoods, eco-towns, and sustainable cities have often involved a concern to design out environmentally damaging activity, such as extensive commuting for work, retailing, and leisure.
“Smart growth” planning has been promoted as a mechanism for minimizing the use of cars and associated resource consumption and pollution. It does this by encouraging population concentration rather than dispersal and the creation of public transport/nonhydrocarbon transport–oriented designs that reduce the need for private petroleum-powered vehicles. These approaches, again, often adopt an ecological modernist perspective, although they have also been linked to the new urbanism movement (which has a range of non-environmental and antimodernist constitutive elements). A second feature of the growing scale of eco-developments has been increasing governmental and corporate business involvement, which has been accompanied by criticisms that they are becoming used as a green marketing or policy gloss to make quite conventional/neoliberal business and policy concerns, such as the construction of new housing, more palatable. On the other hand, it is important to recognize the continuing presence, and innovative role, of a series of less commodified, less state-sanctioned eco-housing developments, many of which, although often drawn into ecological modernist developments, owe their origins to deeper green perspectives on design and development.

Deep Green Design

Among the features identified as key elements of eco-centric or deep green attitudes is a concern to establish nonexploitative relations with nature and a sense that people are linked to and are a part of nature, such that it not only provides material limits to human activity but is also a source of behavioral obligations and prescriptions and, indeed, of design ideas and ways of thinking. Advocates of deep green perspectives also tend to be highly critical of the technology and economic growth–focused perspectives on design and development, even though some of them have been influential agents in the construction of such perspectives.

Victor Papanek, for example, whose work has been discussed in relation to ideas of appropriate technology, can be viewed as adopting a deep green sense of holism in his promotion of green design as “design for the real world.” By this, he meant that there are not only unaddressed human needs but also an environment that, although in the process of being defiled by poorly designed objects and structures, he viewed as productive of a collective unconsciousness or spirituality to which designers needed to become attuned. Papanek also espoused the view that biological systems could provide prototypes for human product designs, a concept he described as bionics and that has also been characterized as biomimicry and biomimetics. These ideas have subsequently been widely applied in mechanical, biochemical, and genetic engineering; architecture; and computing and information/communications technologies. Even Schumacher, whose orientation toward technology exhibited a clear anthropocentric focus, suggested that human societies needed to learn from the principles and laws of nature.

A further feature identified as significant in many eco-centric perspectives is an emphasis on self-reliance and communality. These concerns can again be seen as important elements in the writings of Schumacher and Papanek, but they have also long been articulated in the anarchist and socialist writings of Peter Kropotkin and Robert Owen as well as by environmentalists. They were also significant in Western countercultural movements of the 1960s and 1970s, through which a series of experiments in autonomous living were conducted in many Western countries. David Pepper has argued that although these linked self-reliance and communal living to environmental issues, they were not of central significance within them, although some of the settlements established during this period, such as Findhorn, have subsequently been viewed as important practical demonstrations of eco-housing design.

Environmental activists often placed an emphasis on autonomy and communality in discussions of sustainable development and green capitalism in the 1980s and 1990s. Many environmentalists frequently espoused counterproductivity arguments, suggesting that any gains from environmentally friendly design would be more than negated by the requirements of capitalism for continuing economic production. In addition, there were also repeated calls to view sustainable development in ways that encompassed social dimensions as well as the environmental and economic aspects emphasized within ecological modernist perspectives. The degree to which these calls reflected a diminution...
or deepening of environmentalism has been subject to much debate, particularly when many governmental policy initiatives seem to emphasize economic and social sustainability issues over environmental ones. It is, however, important to note that away from the policy arena, notions of autonomy and communality were often being practically integrated with notions of environmentalism and sustainable development through the design and construction of eco-housing and low-impact residential developments. Many of these developments sought to be self-sufficient or operate “off-grid” through becoming independent of any external inputs of energy and resources. Moreover, in many instances, the concern for ecological independency was linked to notions of social independence/autonomy, with residents seeking to exercise dweller control over the house-building process. Many of these developments have intentionally sought out marginal positions. Additionally, as noted above, they have also become used as models by ecological modernist design movements, even though the latter’s emphasis on technology and economic growth is often explicitly rejected by their designers, who adhere to deep green or other antimodernist values.

Martin Phillips

See also Deep Ecology Movements; Ecological Modernization; Greenbelts; Green Building; New Urbanism; Smart Growth; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Production

Further Readings


GREENHOUSE GASES

Many chemical compounds found in Earth’s atmosphere act as greenhouse gases (GHGs). These gases allow sunlight to pass through the atmosphere; however, when the sunlight is reradiated back toward space as infrared radiation, GHGs absorb the infrared radiation and trap the heat in the atmosphere and at Earth’s surface. GHGs allow Earth to be habitable—without them, the average temperature of the planet would be −18 °C instead of 15 °C. However, human actions are increasing the atmospheric concentrations of GHGs, resulting in an enhanced greenhouse effect that is warming Earth’s climate and increasing the incidence of extreme weather events.

The most abundant GHGs are naturally occurring: water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). There are also many other, highly potent, anthropogenic GHGs. Three of these also deplete the stratospheric ozone layer: chlorofluorocarbons
(CFCs), hydrochlorofluorocarbons (HCFCs), and bromofluorocarbons (i.e., halons). These ozone-depleting substances (ODSs) are controlled under the Montreal Protocol on Substances That Deplete the Ozone Layer of 1987, and as a result, their impact on both ozone and the greenhouse effect has been greatly reduced. Other anthropogenic fluorine-containing halogenated substances do not deplete stratospheric ozone but are potent GHGs. The most important of these are collectively called the F-gases and include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF\textsubscript{6}). Numerous other minor trace gases complete the inventory of GHGs.

The contribution of a gas to the greenhouse effect is a result of both its characteristics and its atmospheric concentration. For example, on a molecule-by-molecule basis, CH\textsubscript{4} is a much stronger greenhouse gas than CO\textsubscript{2}, but it is present in much lower concentrations, so that its total contribution is smaller. When these gases are ranked by their contribution to the greenhouse effect, the most important ones (excluding ODSs) are water vapor, CO\textsubscript{2}, CH\textsubscript{4}, and O\textsubscript{3}, followed by N\textsubscript{2}O and the three F-gases.

### Institutional Framework

In 1992, 157 countries signed the United Nations Framework Convention on Climate Change (UNFCCC) and agreed to a common objective: “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” As of 2009, 192 parties, including the European Union, have ratified the UNFCCC. This treaty focused attention on “anthropogenic” GHGs, that is, those GHGs that are either the direct result of human activities or the result of natural processes that have been affected by human activities.

The Kyoto Protocol (Japan) to the UNFCCC was negotiated in 1997; it focused on six GHGs (CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O, SF\textsubscript{6}, HFCs, and PFCs). This treaty established legally binding commitments for the reduction of these six gases by the industrialized nations, as well as general commitments for all member countries. The Kyoto Protocol went into force in 2005, and as of 2009, 181 parties, including the European Union, had ratified it. Under the Kyoto Protocol, the industrialized countries agreed to reduce their collective emissions of the six GHGs by 5.2% relative to the year 1990. Because of its dominant influence in global warming and climate change, the rest of this entry focuses on CO\textsubscript{2}.

### Radiative Forcing and Climate Sensitivity

Radiative forcing is used to quantify the effect of increased concentrations of GHGs on the climate. It is a measure of the global energy balance, relative to preindustrial times. Forcings are influences that “push” the climate toward overall warming (positive forcing) or cooling (negative forcing). This phenomenon is measured as the alteration in global average atmospheric radiation flow in watts per square meter (W/m\textsuperscript{2}). The sensitivity of Earth’s climate to forcings is defined as the change in average surface temperature produced by a forcing of 1 W/m\textsuperscript{2}.

Through the study of ancient ice cores from Antarctica, it is possible to compare concentrations of CO\textsubscript{2} in the atmosphere with temperature variations over the past 400,000 yrs. (years). These records support a sensitivity of \(\sim 0.75 \degree \text{C W}^{-1} \text{m}^{-2}\). Sensitivity is also sometimes expressed as the change in average surface temperature that would be produced by a doubling of CO\textsubscript{2} from its preindustrial concentration of 278 ppmv (parts per million by volume), which corresponds to a forcing of 3.7 W/m\textsuperscript{2}, or \(\sim 2.7 \degree \text{C}\). Such analysis has led researchers to conclude that most of the observed increase in globally averaged temperatures since the mid 20th century is “very likely” due to the observed increase in anthropogenic GHG concentrations. In the terminology of the Intergovernmental Panel on Climate Change (IPCC)—the international scientific organization that assesses the scientific, technical, and socio-economic information relevant for understanding the risk of human-induced climate change—“very likely” implies a 90% or greater probability of occurrence.

The global increases in CO\textsubscript{2} concentration are due primarily to fossil fuel use and land use change, while those of CH\textsubscript{4} and N\textsubscript{2}O are primarily due to agriculture. Reducing emissions of GHGs affords significant near-term opportunities for addressing the underlying causes of climate change. Many of
These GHGs have global warming potentials (GWPs) far higher than that of CO\textsubscript{2}.

According to the IPCC, long-lived anthropogenic GHGs in 2005 exerted a total radiative forcing of \(\sim 2.64 \text{ W/m}^2\) (Figure 1). CO\textsubscript{2} accounted for 63\% of this total, and non-CO\textsubscript{2} global GHG emissions of CH\textsubscript{4}, N\textsubscript{2}O, and high-GWP gases accounted for the remaining 37\% (including ODSs). Since the Industrial Revolution, GHG concentrations in the atmosphere have risen rapidly, with CO\textsubscript{2} concentrations increasing from 280 ppmv in the early 1800s to a current level of \(\sim 375 \text{ ppmv}\). From just 1995 to 2005, CO\textsubscript{2} radiative forcing increased by 20\%, the largest change for any decade in at least the past 200 yrs.

About 80\% of anthropogenic GHG emissions are energy related, principally from fossil fuel combustion. As a greater portion of the world’s population gains access to electricity and commercial fuels and with continued population growth, GHG emissions and concentrations in the atmosphere are expected to continue to increase over the 21st century. Numerous scenarios have been developed, with concentrations ranging from 350 to 650 ppmv and higher in the year 2100. As scientists begin to characterize the consequences of such unprecedented interference with the global climate, attention is being focused on mitigation actions. Technology, policy, and behavioral options to reduce GHG emissions are numerous, mirroring the complex of emission sources that exist. GHG sources and mitigation options are summarized below. Types and sources of U.S. GHG emissions are summarized in Figure 2.

**Sources of CO\textsubscript{2} and Their Control**

CO\textsubscript{2} emissions come principally from the burning of fossil fuels, although land use changes, forestry, and other industrial activities such as cement manufacturing are also important. There are three strategies for addressing CO\textsubscript{2} emissions from fossil fuels: (1) improving energy end-use efficiency, (2) de-carbonizing the energy supply sector, and (3) capturing and storing carbon to prevent its release into the atmosphere. These are addressed in turn.

**Energy End-Use Efficiency**

End-use energy efficiency offers some of the largest and least-cost near-term opportunities for large-scale GHG mitigation. Numerous energy efficiency improvements are currently available and cost-effective and are already displacing CO\textsubscript{2} emissions.

On a global scale, combustion of transportation fuels accounts for 20.3\% of CO\textsubscript{2} emissions. Over the next few decades, the transportation sector is expected to be one of the fastest-growing sources worldwide of GHG emissions. Promising technologies to reduce transportation energy use include lightweight materials, improved vehicle efficiency, electric fuel engine hybrids, clean diesel engines, and hydrogenated low-sulfur gasoline. Other options include alternative fuels such as ethanol, natural gas, electricity with storage, and biodiesel. In aviation, the next largest category of transportation energy demand after highway use, GHG emissions could be lowered through new technologies, including improved engine designs, fuel blends, and air traffic management systems. Finally, reductions could result from curbing the growth in vehicle miles traveled (VMT), modal shifts, and optimized transportation logistics.

The built environment accounts for about one third of primary global energy demand and is a major source of energy-related GHG emissions. Over the long term, buildings are expected to

**Figure 1** Global mean radiative forcing of the climate system in 2005 by long-lived greenhouse gases (measured in watts per square meter)

continue to be a significant component of increasing global energy demand and a large source of CO₂ emissions, driven in large part by the continuing trends of urbanization, population and income growth, and longevity of building stocks. In the United States, the energy services required by residential and commercial buildings contribute ~38% of CO₂ emission. Technologies to reduce GHG emissions include the following:

- Advanced appliances, lighting, and heating and cooling equipment
- Advanced building envelope components, including roofs, walls, windows, and foundations
- Integrated building design, construction, and operation, including the optimal integration and control of components

The industrial sector is the largest of the end-use sectors, consuming more than 50% of the delivered energy worldwide and producing a commensurate share of CO₂ emissions. Global energy consumption in this sector is projected to increase by an average of 1.8% per year from 2004 through 2030. GHG-intensity-reducing concepts for industry include technologies that increase the efficiency of process heating and process and design enhancements that can improve quality, reduce waste, reduce the intensity of material use, and increase in-process material recycling. Industrial facilities can implement direct manufacturing processes, which can eliminate some energy-intensive steps, thus both avoiding emissions and enhancing productivity. On the supply side, industry can self-generate clean, high-efficiency power and steam; it can also create products and by-products that can serve as clean-burning fuels, including the use of combined heat and power and cascaded heat.

**Low-Carbon Energy Supply**

Transforming the energy supply sector to reduce GHG emissions will require deployment
of innovative GHG-reducing technologies. For example, low-emission fossil fuel technologies, such as integrated gasification combined cycle power plants, can improve the efficiency of coal combustion by a few percentage points and have a significant impact on aggregate GHG emissions. Hydrogen has the potential to supplant hydrocarbon fuels and deliver net GHG reductions, though this depends on the source of hydrogen. Renewable power and fuels constitute a class of technologies that vary widely in terms of market readiness and penetration but have large GHG mitigation potential as a whole. In addition, nuclear fission substantially contributes to low-carbon power production and has significant potential to supply more in the future.

**Carbon Capture, Storage, and Sequestration**

Carbon capture and geologic storage technologies are expected to work in conjunction with the transition of low-carbon fuels to reduce GHG emissions from large concentration sources such as fossil power plants and industrial facilities. Capture and storage are supported by domestic demonstration projects, international collaboration efforts, and information programs. Terrestrial sequestration in soils or trees offers a potential sink for CO₂ that cannot be stored in geologic formations, and the large U.S. land base offers considerable potential for increasing terrestrial sequestration capabilities. However, this great opportunity comes at a relatively high cost for the many individual landowners who must change their practices and acquire additional skills or equipment to increase their land’s sequestration capacity.

**Comparisons Between Developed and Developing Countries**

The global contribution of CO₂ emissions is dominated by the developed nations. In 2005, members of the Organization for Economic Cooperation and Development (OECD) were responsible for 48% of global CO₂ emissions, and the United States alone was responsible for 21%. According to the U.S. Energy Information Administration, world CO₂ emissions will grow from 28 billion metric tons in 2005 to 42 billion metric tons in 2030. A majority of this growth will take place in non-OECD countries—especially China, India, and the Middle East. As a result, by 2030, OECD countries will account for only 37% of the total CO₂ emissions.

The global contribution of non-CO₂ GHGs is also highest in developed nations (Figure 3). While there have been reductions in CH₄ emissions, for instance, from coal mining and landfills in industrialized nations due to the restructuring of key industries, the emissions of the developed world remain much higher than those from developing countries. The ranking of regions from 1990 through 2020, in descending order, is forecast to be member countries of the Organization of Economic Cooperation and Development (OECD) and the European Union (EU), China, southeast Asia, non-EU countries of the Soviet Union, Latin America, Africa, and the Middle East. As with CO₂, the growth rates of non-CO₂ GHGs are higher in the developing nations than in the industrialized nations because of their rapid industrialization, expanding economies, and more rapidly growing populations.

**The Urban Geography of Greenhouse Gas Emissions**

Attention is beginning to focus on the urban geography of GHG emissions as community leaders realize that they need to play a critical role in the push to restrain emissions. Fortunately, many metropolitan areas offer major advantages for doing that, as illustrated in a recent study funded by the Brookings Institution that quantifies, for the first time, the carbon footprints of the 100 largest U.S. metropolitan areas. Topmost among the stories told by the study is the large degree of variation between the carbon footprints of U.S. metropolitan areas, based on the energy used in residential buildings and for surface transportation (i.e., cars and trucks). In 2005, per capita CO₂ emissions were highest in Lexington (Kentucky) and lowest in Honolulu—the average resident in Lexington emitted 2.5 times more carbon from transport and homes than the average resident in Honolulu.

Along with this dramatic variation between metropolitan areas, the study also reveals...
that urban areas with high-density, compact development and rail transit offer a more energy- and carbon-efficient lifestyle than sprawling, auto-centric areas. For example, many metropolitan areas with small per capita carbon footprints, such as New York, San Francisco, San Diego, and Los Angeles, have sizable rail and mass transit riderships, while low-density metro areas such as Nashville and Oklahoma City are prominent among the 10 largest per capita emitters. There are exceptions, however. Washington, D.C., Baltimore, and Atlanta all have high rail transit ridership but also have larger than average carbon footprints, illustrating that other factors can offset the GHG savings from rail transit ridership, such as large emissions from freight transportation and coal-dominant electricity.

Twenty-four percent of all highway fuel consumed and CO₂ emitted within the 100 largest U.S. metro areas comes from trucks, as opposed to cars. Growth in truck traffic is now outpacing growth in car traffic, and truck VMT (vehicle miles traveled) is expected to grow by more than 2% annually through 2020 in the United States.

Heavy reliance on coal-generated electricity for air conditioning and heating also contributes to the large per capita carbon footprints characteristic of many urban areas in the American South and Midwest. For example, the Washington, D.C., metropolitan area’s residential electricity footprint was 10 times larger than Seattle’s

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**Figure 3** Total non-CO₂ emissions by region (metric tons of CO₂ equivalent). These geographic statistics highlight the fact that mitigation measures and strategies are needed worldwide.

footprint in 2005, partly because the area’s mix of fuels includes high-carbon sources of electricity such as coal, while Seattle draws its electricity largely from carbon-free hydropower.

CO₂ emissions show strong regional trends. The Mississippi River roughly divides the country into high and low emitters. In 2005, all but 1 of the 10 largest per capita emitters were located east of the Mississippi. Most of the metro areas with the smallest per capita footprints were located in the west. A north-south divide is also apparent, with seven of the highest per capita emitters located south of the Mason-Dixon Line, including two each from Tennessee, Ohio, and Kentucky. Thus, the passage of climate legislation aimed at curbing GHG emissions in the United States would have highly geographically differentiated impacts (see Figure 4).

Altogether, federal prometropolitan climate policies could place large urban areas at the forefront of problem solving on energy and climate challenges. Just as there are strong geographic variations in GHG emission trends at the global scale, so too are there variations at the regional and urban scales.

*Marilyn A. Brown*

*See also* Anthropogenic Climate Change; Atmospheric Pollution; Carbon Cycle; Carbon Trading and Carbon Offsets; Climate Change; Climate Policy; Energy Policy; Energy Resources
Further Readings


GREEN REVOLUTION

See Environmental Impacts of Agriculture

Derek Gregory is one of contemporary human geography’s leading theoreticians. His early career was marked by critiques of location theory, spatial diffusion, and humanistic geography. In the 1980s, he introduced geographers to Anthony Giddens’s theory of structuration, linking it to the tradition of time-geography. He also injected social theory into historical geography, including studies of the uneven spatiality of class struggle in England during the Industrial Revolution. Such studies of the origins of modernity enticed geographers to unveil its historically specific nature and reveal it as a particular power-knowledge configuration.

Gregory’s exploration of postmodernism, including its general distrust of broad, overarching theoretical paradigms, raised the importance of spatiality to new heights: Geographies, he insisted, are not simply passive reflections of some aspatial social structure; rather, space is inevitably an active participant in the formation of social relations and their changes over time.

The book Geographical Imaginations, published in 1994, was a well-received elaboration on the ways in which seemingly different theoretical approaches reflected historically specific “scopic regimes,” ways of seeing and knowing the world that appear consistent and complete within their own frames of reference. Since the Enlightenment, Western social science, including geography, has subscribed to the notion of a Cartesian observer, who is detached, all-knowing, and objective, a view that led to what Gregory calls the “world-as-exhibition.” This notion underlies many seemingly disparate perspectives, including Marxism and positivist conceptions, and confers the power to know and define the world—both social and natural—one rational, presumably male, all-knowing ego. Within geography, it was reflected in the triumph of abstract
space over lived experience, a position made possible only if representations of the world are held to be detached from the world they reflect. In contrast, Gregory argues that every theoretical position is necessarily incomplete and situated, linked to a power interest, and reflective of its utility in social life.

More recently, drawing on works concerning Orientalism, Gregory has focused on European colonial representations of non-Western spaces and peoples. As a power-knowledge relation, the active “geo-graphing” of various parts of the globe was an integral part of Western administrative control of colonized regions. The colonial geographical imagination demarcated space and brought alien territories into Western frames of understanding in a manner that drew critical boundaries between identities, the self and the other, whites and nonwhites, and so on. Empirically, Gregory’s postcolonial work focused largely on the Middle East, particularly European and American representations of Egypt in the late 19th and early 20th centuries. In the 19th century, as Egyptology became fashionable, Egypt occupied a central ideological position in the evolving self-conception of the West as both near and distant, foreign and familiar, ancient yet stagnant. Gregory reveals how Western imaginative geographies were laced with patriarchal, sexualized, and often racist imagery that effectively “othered” Arabs in their own lands as Egypt was thoroughly “geo-graphed” by a panopticonic foreign authority. In The Colonial Present, he extended postcolonialism into a critique of the so-called war on terror in Iraq, Palestine, and Afghanistan, revealing it to be a war of terror against people rendered invisible by Western discourses that marginalize Muslims.

Continuing in this vein, Gregory has more recently explored the spatiality of U.S. human rights abuses at the military base and prison at Guantanamo, Cuba, drawing on the work of the Italian philosopher Giorgio Agamben. The dominant discourses defending American policies portrayed Guantanamo as a necessary corrective to the unjustified and irrational actions of insurgents. The volume Violent Geographies, which Gregory co-edited with Allan Pred, offered an in-depth overview of how political terror, daily life, and space were intertwined in a variety of different contexts, including Hindu and Muslim fundamentalism, the geographies of the terrifying war on terror, and the ways in which violence of all types is discursively sanitized.

Gregory has emphatically stressed the importance of historical context in academic work, a move that thwarted the aspirations of Enlightenment modernists to construct universal interpretations independent of time and space. He has remained steadfast in his insistence that geographies are peopled, that time and space are made by ordinary folk, and that the outcomes are always contingent and never predetermined, even if, in contrast to overly structuralist interpretations, they are likewise never random or chaotic. His works have decisively demonstrated the need to understand capitalism in discursive terms, and he has been an acute observer of the roles played by language in the process of representation. He has remained sensitive to the politics of representation, the ways in which all forms of understanding are inescapably entwined with temporally and spatially varying regimes of power-knowledge: Discourses simultaneously reflect and constitute the relations they depict and that give rise to them. Finally, Gregory’s turn to postcolonialism has helped awaken the discipline to the profound but often invisible ways in which geography as discourse was complicit in the systematic othering and dehumanization of non-European peoples, a process that continues today in Western policies toward the Muslim world.

Barney Warf

See also Agamben, Giorgio; Critical Human Geography; Geographical Imagination; Giddens, Anthony; Postcolonialism; Pred, Allan; Structuration Theory; Time-Geography

Further Readings

GROSS DOMESTIC PRODUCT / GROSS NATIONAL PRODUCT

Gross domestic product (GDP) and gross national product (GNP) are widely used measures of the value of total economic activity of a region in a given period of time, typically a year. While these indices may be estimated for subnational regions, they are most commonly used in reference to countries. Thus, while GDP and GNP are primarily economic measures, they are also inherently spatial because they vary in absolute and per capita terms widely across the world.

GNP assesses the total value of the goods and services produced by a given national group of people in a given year. Because statistically total output must equal total income and expenditures, it is also a measure of those two other dimensions of the economy. In typically macroeconomic accounting, GDP is the sum of consumption, gross investment (not counting depreciation), government spending, and net exports. This measure is also equal to total employee income (wages and salaries) and profits (returns to businesses); thus, GDP is sometimes called gross domestic income. GDP may also be regarded as the sum of all profits added at different stages in production from raw material to final good.

GDP differs from GNP in that the former refers only to the output of a country rather than to its nationals, who may live beyond its borders. GNP, in contrast, includes the output of nationals abroad. Given the growing significance of extranational production, GDP has slowly replaced GNP as the most common measure of national output. For example, in 2006, the U.S. GNP was $11.059 trillion, including $55 billion in receipts from abroad, making the U.S. GDP equal to $11.01 trillion. As foreign incomes have increased around the world, the use of GDP as a measure of economic activity has gradually declined in favor of GNP.

In 2007, the world’s GDP was roughly $54.6 trillion; of these, the GDP of the United States was about $13.9 trillion (Figure 1), followed, in order, by China ($7 trillion), Japan ($5 trillion), Germany ($2.8 trillion), and France, Russia, the United Kingdom, and Italy at approximately $2 trillion each.

GDP divided by the total population of a region at a given moment yields GDP per capita, the most common measure of average individual income (or lack thereof), productivity, and economic development. GDP varies widely among the world’s states (Figure 2), ranging from a high of more than $40,000 in Scandinavia in 2007 to a low of less than $300 in Mozambique, Congo, and Niger. Roughly one half of the world’s population lives on a GDP per capita of less than $2 per day, although this measure excludes the informal economy and noncommodified forms of activity such as subsistence production. GDP per capita is thus a widely deployed metric of uneven spatial development, and its map reflects the pronounced bifurcation between the First and Third Worlds. Growth rates of GDP per capita measure the extent to which average incomes are changing.

However, as with GNP, GDP has been criticized as a measure of economic wealth in that it only includes commodified activity and ignores substantive areas of activity such as subsistence production, unpaid activities such as housework, and the informal economy and that it is vulnerable to both exchange rate fluctuations and inflation rates. Feminists have criticized these measures...
Figure 1  Major world GDP, 2007 (in U.S. dollars). GDP reflects, among other things, the size of a country’s population, its resource base, and productivity. The United States is the only country that is simultaneously large and productive.  


Figure 2  Map of GDP per capita, 2007. Although it is an imperfect measure of average incomes, GDP per capita is the most widely used. Its spatial variations reflect the world’s wealth and poverty (i.e., uneven development).  

as valuing only male labor relative to female labor. Neither does GDP per capita include the cost of living; for this reason, some researchers prefer measures of purchasing power parity. Moreover, GDP per capita is an average that may conceal large internal inequalities in income. Both GNP and GDP, therefore, are imperfect measures. Some theorists have called for nonmonetary measures of national wealth, such as the amount of time necessary to purchase a given commodity, per capita energy use, or health statistics, all of which speak to the quality of life rather than simply economic activity. Bhutan, for example, uses a measure called gross national happiness.

Barney Warf

See also Regional Economic Development; Uneven Development

Further Readings


Remote sensing (RS) of Earth’s environment using airborne and satellite-borne sensors has greatly improved our ability to describe and measure the characteristics of Earth’s atmosphere, oceans, land surfaces, and dynamic processes over time and space. Products derived through remote sensing enhance our geographical understanding of the environment and how humans interact with and/or affect the environment. Ground reference data (GRD) are critical to the creation of accurate and useful RS products. GRD provide information about actual conditions of features or phenomena of interest and are used for calibration and validation purposes.

GRD may be in the form of point-based information, plot samples, or maps with areal units (e.g., polygons) having thematic or continuous data. Before GRD are collected, the exact type and nature of the GRD needed should be carefully considered. **Thematic data** describe classes such as land use type or vegetation type. **Continuous data** describe attributes that vary continuously over space or time, such as percentages, counts, and sizes. For example, continuous data may describe the percent cover of impervious surface within an urban area, the temperature of a portion of ocean surface, or the biomass within a stand of rain forest. GRD should be collected or processed to be in a form comparable with the RS data they are to support.

Collection of GRD may be accomplished by in situ visits and drive-by mapping. GRD are more accurate than reference data collected using other methods (e.g., aerial reconnaissance, interpretation of relatively high-resolution imagery, or compilation of existing ancillary data). GRD collected during in situ visits are considered the most accurate and are often referred to as **ground truth** data. The collection of in situ GRD can be expensive and time-consuming.

GRD are collected to better understand features or phenomena of interest and to calibrate and validate RS products designed to map these features/phenomena. Calibration is the process of using GRD to train a classification algorithm or biophysical data estimation model. Validation is the process of assessing the accuracy of the final product. GRD samples should be divided so that some are used for calibration and the remainder for validation. This ensures that accuracy assessment results are independent.

GRD contain error and uncertainty and thus should not be considered as “ground truth.” These errors are associated with things such as timing differences between GRD and RS data, spatial location errors of GRD and co-location errors relative to RS data, human measurement/interpretation errors, and errors associated with the scale of GRD. Scale errors include the use of minimum mapping units that are different from those associated with the RS data and delineation/digitizing error due to map/image display scale.

Lloyd L. Coulter

See also Aerial Imagery: Interpretation; Image Processing; Remote Sensing
Groundwater refers to the saturated layer of Earth’s crust extending beneath the land surface to a depth where solid rock does not permit the movement or storage of water. The widespread geographical distribution of groundwater and its usually high quality for human consumption, agriculture, and other uses make this a resource of global importance; it accounts for a third of the planet’s total volume of water outside the oceans, or close to 98% of all freshwater outside ice caps and glaciers. The spatial occurrence and quality of groundwater are not uniform, which is the result of geology, climate, surface water interactions, and, increasingly, human use and contamination. There is a growing recognition that a comprehensive understanding of groundwater must consider its multiple and interconnected physical, hydrogeological, and human use dimensions.

This entry is organized as follows: A brief physical characterization of groundwater in the hydrological cycle is followed by a description of its geographical distribution and importance, which leads to assessment of groundwater use, quality, and sustainability challenges. The entry concludes by outlining human organizational and institutional aspects, along with a synthesis of the human-environment dimensions of groundwater.

Groundwater Hydrology

Active groundwater is conventionally distinguished as the portion that circulates in contact and exchange with Earth’s surface hydrological cycle; this accounts for approximately half of the total groundwater. The remaining deep groundwater portion occurs within Earth’s crust and is largely inaccessible to surface hydrologic interaction or human use. Geological conditions, specifically geochemical processes and residence times, influence the quality of groundwater. Much deep groundwater is considered to be of a quality that is not suitable for ecological or human purposes; for example, it frequently has high dissolved mineral content as a result of prolonged chemical interaction or deposition from saline ocean water over geological timescales. Shallow groundwater extensively interacts with surface water over timescales that vary from days to millennia.

Aquifers are the spatial units of rock, alluvium, and other subsurface materials where groundwater occurs, and they are separated from other aquifers by nonporous geological formations that impede the subsurface flow of water. Aquifer properties include porosity, rock fractures, conductivity (groundwater movement that a pressure gradient produces), and transmissivity (conductivity over the depth of the water-bearing strata). These properties, coupled with groundwater pressure that results from elevation differences of water levels in the aquifer, determine the rates of groundwater extraction that pumping will produce. Drawdown and cone of depression refer to localized groundwater-level effects resulting from extraction.

Groundwater is recharged vertically from the surface infiltration of rainfall, other atmospheric precipitation, or water bodies, including lakes, rivers, wetlands, and estuaries. Under certain aquifer conditions, recharge may occur laterally from surface water bodies. Water occurring in the immediate near-surface, weathered soil layer, often coinciding with the depth that plant roots will penetrate, is referred to as soil moisture. Below this, water percolates in the unsaturated vadose zone (the area between the surface and the saturated zone) and deeper to saturated layers of the aquifer, commonly referred to as the water table. Alluvial deposits often result in unconfined aquifer conditions. In contrast, impervious strata, for example, solid or low-porosity rock or clay layers, can result in confined or semiconfined aquifers and, depending on the groundwater pressure, may cause water to flow freely to the surface in artesian wells.

Depending on the water levels, groundwater may reside indefinitely in aquifer storage, or it
may discharge to the surface or to oceans. An important process of groundwater discharge supplies the base flow (minimum dry-season surface flow) in streams and rivers during periods of low precipitation and runoff. A special class of ocean-aquifer interactions accounts for the salinity of groundwater in near-coastal areas. Islands in the ocean often have a lens of low-salinity fresh groundwater perched above the underlying saltwater. The saline-freshwater interface is subject to disruption, for example, through pumping, which may cause salinity ingress to otherwise freshwater aquifers.

It is important to briefly summarize mathematical modeling approaches to groundwater occurrence and movement and to the fate and transport of contaminants. Early mathematical development proceeded from hydraulics and improved on static water budgets that assumed uniform aquifer mixing. Groundwater flow models require extensive parameterization (definition and quantification of multiple variables) and data sets based on extensive monitoring of groundwater levels and flow processes. Models such as MODFLOW are based on finite-element grids that represent the aquifer in three dimensions. Additionally, these models are capable of simulating the geochemical interactions of specific contaminants. Groundwater models are developed and run for research and operational purposes, for example, by agencies charged with the management of water resources.

Geographical Distribution

The occurrence of groundwater is determined by three principal factors: (1) aquifer characteristics that permit recharge and storage of groundwater, (2) precipitation or surface water availability for recharge (bearing in mind the extended, millennial scales of storage and circulation), and (3) human use that may drive aquifer depletion if extraction is significantly in excess of recharge. Despite its recharge from precipitation, groundwater may be abundant in aquifers in low-precipitation (arid and semiarid) regions. As a result, it is a resource of critical importance in the Middle East, North Africa, South and West Asia, Australia, Western North America, and parts of South America and Europe. Due to its ease of access and temporal dependability compared with surface waters that are often prone to drought and intermittent depletion, groundwater is also extensively used in higher-precipitation humid regions.

Surveys to quantitatively estimate groundwater storage have been conducted at the national and subnational levels; however, these are based on inconsistent methods and differing assumptions of subsurface aquifer characteristics. Reporting problems similarly plague groundwater use data. It is estimated that globally, India is the largest user of groundwater (150 km³/yr. [cubic kilometers per year]), followed by the United States (100 km³/yr.), China (75 km³/yr.), Pakistan (45 km³/yr.), Iran (45 km³/yr.), and Mexico (28 km³/yr.).

Groundwater Use

As indicated above, groundwater is increasingly used for human purposes, including (in order of estimated volume currently extracted) agriculture and livestock, potable water supply in urban and rural areas, power generation, and industrial uses. Historically, humans devised ingenious means to use and extract groundwater. Desert oases occur where shallow groundwater accumulates at the surface. Lift devices from shallow open wells used human and animal draft power and included the Archimedean screw, Persian wheel, and animal skin bailer. Wind-powered and water flow–powered lift devices became important with advances in mechanics and materials. Qanats, sloped horizontal tunnels to intercept groundwater within a hillside and convey it by gravity to the surface, were developed in Persia as early as 2,500 yrs. ago. This technique, with some innovation and under a range of names, spread in Central Asia and farther west, to North Africa, Southern Europe, and the Americas, as well as east to parts of China, Japan, and the Philippines. Functioning qanats can still be found.

The 19th-century advent of mechanized pumps, driven initially by steam power and subsequently by electrical motors or hydrocarbon-fueled engines, resulted in widespread tapping of aquifers for human use. Early examples of groundwater-based regional and economic development, particularly for urban expansion and agricultural irrigation, include the American West, Mexico, Spain, the Middle East, India,
Groundwater development was intricately linked with population growth in urban centers and rural areas alike, human occupation of regions previously considered uninhabitable for lack of access to reliable water supplies, and increased food production. Rural electrification programs in the early and mid 20th century, coupled with the development and reduction in costs of pumps and related irrigation technology, drove the expansion of groundwater-based agriculture, which by a large margin exerts the greatest demand on groundwater resources. In numerous locations, falling water levels resulted from extraction in excess of renewable groundwater supplies. In other aquifers with exceedingly low or nonexistant recharge, extraction is referred to as groundwater mining, or use of fossil groundwater.

Numerous regions where population growth as well as economic development and diversification away from agriculture were facilitated by reliance on intensive groundwater use began to show symptoms of aquifer depletion: rising costs of extraction (both for deepening and operating wells), declining water quality, land surface subsidence (where compaction of aquifer layers pumped dry caused non-uniform settling and often large surface cracks or sinkholes), and drying of surface streams previously fed partially or wholly by groundwater discharge, among other impacts. This has resulted in serious risk to groundwater-dependent human populations and ecosystems. Related impacts of intensive groundwater use include (a) the mobilization of geogenic sources of arsenic, resulting in often serious contamination of water supplies in some of the world’s most densely populated regions, particularly the lower Ganges-Brahmaputra river basin in Bangladesh and parts of India and Nepal; (b) fluoride contamination of groundwater; and (c) salinity ingress in coastal aquifers as well as salt buildup in intensively irrigated soils in arid regions. It is also now recognized that recharge processes can be exacerbated by climate change-driven precipitation variability coupled with human modification of the land surface, for example, compaction of agricultural soils or sealing over urban spaces through paving and roofing. Drought and flood cycles and the variability of surface water resulting from climate change processes may induce additional human reliance on groundwater as a dependable source of supply to meet a range of demands. At the same time, groundwater use may exert feedbacks on the climate system via greenhouse gas emissions resulting from the generation of power to pump the groundwater. Human use of water is extremely energy intensive; for example, India uses a third of its electrical power to pump groundwater, and Southern California uses a fifth of its power for the full cycle of water service provision.

In sum, groundwater development has been a primary driver of urban and rural growth and prosperity but has often resulted in unsustainable aquifer depletion. Regions considered emblematic of the groundwater extraction-depletion trajectory include the southwestern United States and the high plains Ogallala aquifer, Central and northwest Mexico, northeast Brazil, the Pacific coast of Northern Chile and Peru, Central Spain, most of North Africa and the Middle East, Iran, Central and northwest India, Central Asia, the North China plains, and Western Australia.

Groundwater Pollution

As indicated above, the quality of groundwater varies naturally as a result of geochemical processes, residence times, and proximity to saline water bodies. Anthropogenic sources of pollution, too, influence groundwater quality, specifically nutrients, salinity, pathogens, and inorganic and organic compounds. Groundwater pollution is exceedingly difficult to reverse or remediate, given the nonuniform mixing, long residence times, and geochemical interactions between pollutants and aquifer materials.

Agricultural fertilizers and human and animal waste are the principal source of nutrients that influence groundwater quality. Nitrogen in its soluble form as nitrate is less reactive with aquifer materials than are other nutrients and is conveyed from surface sources and land uses via percolation to the underlying aquifer. In cases where groundwater is used to supply drinking water for human settlements, high concentrations of nitrate are a particular concern due to the risk to human health. Blue baby syndrome can be fatal for infants who consume water, formula, or other food prepared using water with high nitrate levels.

Pathogenic microorganisms including bacteria, protozoa, and viruses occur in groundwater as a
result of human activity and the transmission of these pathogens to the underlying aquifers. Aerobic conditions above the saturated aquifer layer and anaerobic conditions below, along with the physical properties of the aquifer (pore size and geometry) significantly influence the distribution and fate of pathogens in groundwater. In general, shallow aquifers with periodic aerobic conditions are more prone to pathogen contamination than are deep aquifers with extended groundwater residence times.

Salinity is a major concern for groundwater quality. Primary salinity may result from groundwater deposition from ocean water over geologic timescales. Secondary salinity has human causes chiefly related to irrigation using water with high dissolved mineral content. As irrigation is applied, crops consume (transpire) water, or it is evaporated from the soil surface, leaving minerals in or on the soil. Subsequent irrigation may involve an extra watering simply to flush the salts out of the root zone of the soil, which may pollute the underlying groundwater depending on the depth to the aquifer. Salinity resulting from irrigation can cause waterlogging where groundwater levels rise to the surface, a condition that is widespread and growing. Waterlogging is common where surface irrigation using canals brings water into an area with underlying saline groundwater that is unusable for irrigation or where topographic conditions make it difficult to drain excess irrigation water. A special case of salinity is presented by irrigation using groundwater that is brackish, that is, with low to medium levels of salinity that some crops may tolerate. Salinity buildup from irrigation with brackish water can be rapid, often putting such areas out of agricultural production.

Finally, a range of inorganic and organic compounds from human sources may impair groundwater quality. Persistent inorganic pollutants in groundwater may include heavy metals; however, these are usually chemically bound to particles that may not easily pass through soil or aquifer material to reach the groundwater. As indicated above, geogenic sources of arsenic represent an important groundwater pollution problem. Solvents, fuel additives, manufacturing byproducts, and other organic constituents that leach into underlying aquifers are representative of organic pollutants that are increasingly recognized as a risk to human health and the environment. The wide range of organic pollutants, some highly site specific, makes it difficult to review their occurrence; however, it should be noted that their traceability and often localized occurrence mean that such contaminants are often targeted for remediation efforts. Given the persistence of groundwater pollutants, remediation may involve physically removing (excavating) contaminated aquifer material. Other approaches, particularly for shallow contaminated layers, include phyto-remediation using plants that selectively take up and bind contaminants in their tissue. Remediation is invariably difficult and expensive, and efforts to prevent groundwater pollution through source control are critical.

Human Organization, Management, and Policy

The use of groundwater for human purposes displays unique organizational characteristics that distinguish it from many other natural resources, including surface water. Because of its geographical distribution, groundwater is accessible to a wide range of users. Technology represents a mediating factor for groundwater use and appropriation and, in cases of aquifer depletion such as those discussed above, forms a mechanism for competition among users. In the early stages of a society’s development and reliance on groundwater, access was considered to be unencumbered by formal institutional arrangements or systems of rights that applied to surface water or other natural resources. In the Western United States, for example, prior appropriation rights to surface water were only subsequently modified and applied to groundwater—often, however, in a manner disassociated from surface water, although hydrologically the two remain connected. Here, groundwater capture by users with the most powerful pumps generated strong competition among users or simply deprived others of access. In other instances, private capture was pitted against public regulation. In the absence of effective regulation, groundwater has been a prime example of the tragedy of the commons, that is, the private appropriation of publicly owned resources that leads to overuse and degradation.

In societies that historically innovated with collective action to use and manage resources, for
example, canal irrigation in Asia or the Andes, the advent of groundwater use represented a marked departure from community norms for access and management of water. As a result, Tushaar Shah refers to groundwater use as atomistic, resulting from private investment even by smallholder farmers of limited economic means. In some instances, these changes have undone community institutions, rule making, and enforcement and compliance, as well as the distribution of labor, costs, and benefits. In other cases—for example, share-based group wells or aquifer-using societies—attempts have been made to bring groundwater and its use under the purview of community institutions. The role of the state in providing or withholding public investment and infrastructure and setting legal frameworks for groundwater use and dispute resolution increasingly overlaps with more localized public and private interests around groundwater.

In the context of mature institutional arrangements, groundwater use is subject to regulation based on legal provisions (e.g., limits to use, spacing of wells, and titling rights) and economic instruments (land, production, or value-added taxation). A growing body of research and case evidence holds significant promise for groundwater regulation through the water-energy nexus, or synergistic management of energy and water—for example, dual water and energy savings based on efficiency and conservation or pricing of energy to manage the demand for water.

Groundwater is no longer considered an insular resource, separate from surface water or unfettered by competing claims over its use. Aquifers are acknowledged to encompass a multitude of uses and users. Competition among agriculture, urban water supply, power generation, and ecosystem needs is increasingly evident, often across national boundaries. Transboundary aquifers are the subject of growing interest among decision makers and researchers, reflecting a trend in the increasing globalization of water issues and paradigms for its management. Transboundary aquifers of particular note include the Guarani aquifer in South America, the Ganges-Brahmaputra-Meghna aquifer system in South Asia, and the Imperial Valley–Mexicali aquifer in Western North America.

Aquifer depletion remains a principal management and policy challenge for human use of groundwater. Various groundwater augmentation and demand management strategies have been attempted at a range of scales. At the very local level, for example, individuals may harvest rainwater runoff from their roofs or fields to recharge individual wells. More concerted efforts have been made at the scale of aquifers in the river basins they underlie. Aquifer conservation plans, conjunctive surface and groundwater use, and integrated river basin management all attempt to influence groundwater use. An important strategy for sustainable aquifer management has been based on importation of surface water, often through transfer from distant river basins. In the United States, Southern California and Southern Arizona aquifers rely on massive pumped delivery of surface water from outside their respective river basins, yet neither region has reached sustainable management targets. Finally, in the sequence of expanding scale, transboundary and global initiatives increasingly address multiple, integrated aspects of groundwater.

Human-Environment Interactions Involving Groundwater

From a coupled human-environment perspective, aquifer physical processes and the attendant water quantity and quality exert mutually causal influences on human groundwater dependence, with critical economic and institutional implications. The rapid development of groundwater over relatively short timeframes of human generations must be considered along with aquifer flow and storage that occur over millennia. Climate change with human and natural drivers that are global in scale adds further complexity to local patterns of human dependence on groundwater.

Christopher Scott

See also Coupled Human and Natural Systems; Environmental Impacts of Agriculture; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Impacts of Roads; Human Dimensions of Global Environmental Change; Hydrology; Open-Pit Mining; Surface Water; Urban Water Supply; Water Needs; Water Pollution; Watershed Yield
GROWTH MACHINE

Growth machine politics suggests that it is the local business elites who are the primary actors in sustaining an image of a city or a region based on a transformational growth ethic. These elites, along with politicians, local media, and utilities, mobilize both to pursue individual economic goals and advocate a viewpoint that growth (at any cost) benefits everyone in the community. This growth ethic seeps into all aspects of community life, including the political system, the agenda for economic development, and the social relations that contribute to local culture. Any issue that deviates from this growth ethic is automatically seen as a potential threat to rents and capital mobility or its exchange value. The rhetoric of these growth machine elites, therefore, tends to revolve around treatment of communities as instruments of profit. This is a doctrine of value-free development, a libertarian-style ethic that sees free markets as the only way to determine the best and highest values for land as well as provide for the economic growth that brings jobs and expands the tax base.

This growth ethic is embedded in long-standing notions of American exceptionalism, where private ownership of property is preferred over transfers of land that benefit the overall public good. Hence, tremendous authority is given to private real estate developers, as well as significant political autonomy at the local level. A growth machine ideology sees the role of local government as limited to only those actions that contribute directly to the economic development of a locality (zoning regulations, property tax issues, etc.). Growth machine elites are also fixed on the notion that urban planning represents a “rational science” to be used for providing order to urban systems while at the same time growing the infrastructure. Consequently, the urban planning process itself has traditionally been at the service of the growth machine apparatus, seen purely as a neutral force in directing home rule. But this planning power, while offering localities a sense of political autonomy, also represents a Trojan horse of sorts. Only the most affluent towns are able to create wealth and privilege from such an arrangement while perpetuating inequalities of wealth among places. Urban planning in this sense is a durable feature of growth machine politics in that it manipulates public resources to serve the economic exchange interests of local elites, often at the expense of the taxpayer. Growth machine politics, therefore, favor economic exchange values over other concerns, such as environmental, cultural, or social issues that are important to the livability of communities. These issues are taken up by local governments only when they can be justified as part of the growth strategy.

Conflicts arise, however, when other stakeholders in a community place a different value on land. For example, environmentalists, heritage preservation activists, or poverty activists see land from a different perspective. For the environmentalist, land is to be ecologically protected, for the heritage activists, it could have historical significance, and for the poverty activist, the way land is developed has implications for accomplishing a larger public good, such as affordable housing availability. All these actors can emerge to challenge the growth machine’s use value of lands in their jurisdiction. As such, understanding the politics of place is fundamentally linked to this conflict between the exchange and use values of land.

Thomas Chapman

See also Governance; Place Promotion; Urban and Regional Development; Urban Geography; Urban Planning and Geography; Urban Policy

Further Readings

GROWTH POLES

Growth poles are geographically pinpointed centers of economic intra- and intersectional linkages that generate positive externalities and spillovers, thereby leading to economic growth. Growth poles can exhibit two opposed forces. If top talent, capital, and knowledge are attracted by the growth poles, regional disparities will increase. If a growth pole’s mobile production factors trickle down to weaker regions, it may lead to regional equilibrium. In aiming to achieve the latter, growth poles have been applied as a regional development concept.

François Perroux considered the combination of different sectors as functional nonbounded economic spaces that result in interindustrial multiplier effects, bringing about innovation and culminating in nonspatial polarization of the economy. In the middle of the 20th century, scientists such as Albert Hirschman and Gunnar Myrdal described the unequal distribution of growth poles in physical space and went on to establish an explanatory model for unequal regional development. The model considers cumulative growth processes in centers where production factors yield higher returns. Subsequently, peripheral regions will lose the mobile production factors, resulting in a downward spiral. However, after a while, the disadvantages of growth poles (e.g., pollution, high property and labor costs) may dominate the advantages, and the growth effects will spread into the hinterland. The likelihood of such a pattern depends on factors such as traffic infrastructure, level of education, sectoral structures, and cultural or social integration between a growth pole and its periphery.

Growth pole protagonists assume a growth trickle down in hierarchical processes from the metropolitan city to the suburbs and from the suburbs to the periphery. Based on this assumption, many industrial and Third World countries tried to use these effects. Since the 1970s, the main mechanisms were to subsidize production plants and concentrate public infrastructure at specific poles within poorer regions or countries. Difficulties occurred through making the idea operationally tractable and combinable with other regional planning concepts such as the central place theory. For instance, what sectors and infrastructures should be promoted at which location? What is the right size of growth poles, and how decentralized should they be when they are distributed across space?

The diffusion of growth effects into the periphery remains a controversial subject in discussions. To date, no decisive empirical evidence of trickle-down effects has been achieved. However, many regional development and adjustment policies are still based partially on the growth pole idea. The currently favored cluster concept, invented by Michael Porter, focuses on the concentration of interconnected businesses and corresponding institutions in physical space. In contrast to the growth-pole concept, the cluster concept puts the emphasis on existent endogenous regional value chains instead of the exogenous creation of growth poles.

Stefan Gaertner

See also Diffusion; Externalities; Learning Regions; Regional Economic Development; Regional Science; Technological Change, Geography of; Uneven Development; Urban and Regional Development

Further Readings


Gullies are a form of linear (soil) erosion that emerge due to the erosive power of concentrated overland flow. Soil and unconsolidated rock are removed up to depths of from 0.5 to several meters, and in the worst case, badlands develop.

The process of gully erosion occurs mainly in landscapes with (climate- and/or human-induced) discontinuous vegetation cover and more or less periodic heavy rainfall events when gullies can develop excessive short-time drainage. These precipitous watercourses are also a sign of severe land degradation and are mainly triggered by land use change, inappropriate cultivation and irrigation systems, overgrazing, urbanization, deforestation, and global change.

Gully erosion can be distinguished into ephemeral and permanent gully erosion. The former can be easily erased with ordinary farming equipment,
but the latter means an irrecoverable loss of land resources.

The process of gully erosion depends on numerous variables—for example, catchment size, vegetation density, land use, substrate characteristics, and slope inclination and length. Furthermore, the velocity and extent of gully erosion depends on the amount of overland flow reaching the top end of the gully (often by convergence of rills), the so-called headcut, which is regressively moving upslope. Thus, gully erosion is conditioned by the properties of the catchment of the gully.

The main processes responsible for headcut retreat are, as mentioned above, headward erosion by overland flow, piping, and undercutting of the headwall by plunge pool development (see images).

The consequences of gully erosion are commonly divided into “on-site” and “off-site” damages. On-site gully erosion destroys and dissects valuable farmland and paths. Off-site, it fills reservoirs or small channels and causes flooding and loss of water quality at the lower reaches. Both damages cause severe socioeconomic problems as loss of arable land or loss of reservoir capacity, which is especially problematic in semiarid to arid regions. Especially in loess areas (Belgium, China, Germany) and regions with a temporary or permanent water deficit (Mediterranean), gully erosion is widely observed and explicitly described. In Belgium and Germany, for example, relicts of former gullying can be found under forests and are believed to be a consequence of former land use changes that can be connected to social problems such as devastating diseases or to climatic change affecting the maintenance of agricultural land and the vegetation cover.

Several techniques have been applied to determine the velocity of gully erosion, such as measuring with benchmark pins, aerial photography (at different spatial scales), GPS (global positioning systems), or dendrochronology. For prevention and control of gully erosion, the variables controlling gully erosion have to be taken into account. Possible controls include restoration of vegetation, changes in land management practices, and technical solutions such as check dams.

Christian Geißler

See also Agricultural Land Use; Basin and Range Topography; Geomorphology; Land Degradation; Land Use; Rill Erosion; Soil Erosion
Arnold Guyot, an important 19th-century Swiss and American geographer, is best known for his pathbreaking work in physical geography. He was also a disciple of Carl Ritter, and he introduced and advanced Ritter’s vision of geography to the United States. Specifically, he advocated investigating and understanding the causes and consequences of the processes creating Earth’s physical and human geography (rather than merely describing them) in terms of Ritter’s teleological understanding of these processes.

Born in Switzerland, Guyot earned his doctorate in physical geography in 1835 at the University of Berlin under Ritter’s direction. Following the completion of his dissertation, and inspired by his friend Louis Agassiz, Guyot undertook groundbreaking research on alpine glaciation. Guyot taught in Switzerland until 1848, when, due to political instability, he left Europe for the United States. From 1851 to 1855, he served as a lecturer on geography education for the Massachusetts Board of Education. In 1854, Guyot was appointed a professor of geology and physical geography at Princeton University, where he remained until his death, conducting important research in meteorology.

Guyot’s influences on American geography began with a series of lectures he gave in Boston shortly after he came to the United States in 1849. The lectures were collected and published as his most famous book, *The Earth and Man: Lectures on Comparative Physical Geography in Its Relation to the History of Mankind*. In this book, Guyot helped introduce Ritter’s ideas to an American audience. Rather than presenting geography as a series of facts to be memorized, Guyot argued for studying geography through a comparative framework. In this view, geography should be seen as an interpretive discipline rather than a dry recitation of information.

Guyot’s influence on American geography was twofold: first, in helping to overhaul and reform geography education in the United States through teacher training and a series of influential geography textbooks, and second, in introducing and advancing a teleological understanding of Earth and its inhabitants. In this latter influence, Guyot, an evangelical Presbyterian who had studied for the ministry before becoming a geographer, was furthering the ideas of Ritter, arguing that a study of Earth’s physical and human geography revealed evidence of a divine plan.

Guyot’s teleological views later came under challenge with the rise of Darwinian perspectives. He extended his belief in the all-encompassing role of God in shaping Earth to suggest relationships between climate and human development, a divinely inspired environmental determinism, which, while unremarkable to some during his era, would be later criticized as racist.

Jonathan Leib

See also Physical Geography, History of; Ritter, Carl

Further Readings


The Hadley cell is an atmospheric circulation cell, named after the English scientist George Hadley. In a 1735 paper, Hadley described the global circulation as consisting of one thermally direct cell in each hemisphere. Hadley’s conceptual model consisted of rising air at the equator and sinking air at the poles. Surface flow was from the poles toward the equator, while upper-level flow was from the equator toward the poles, completing the cell. Hadley’s early contribution did not consider the rotation of Earth, which results in the Coriolis force, an apparent deflection of moving air to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. His description also did not consider seasonal variations due to the annual revolution of Earth around the sun. In the early 20th century, regular meteorological observations became more widespread, and a clearer picture of the global circulation emerged. In a contemporary context, the term Hadley cell is used to describe the circulation in the tropics and subtropics, which is thermally direct as Hadley had envisioned. When combined with seasonal variability and deflection of air due to Earth’s rotation, the Hadley cell is a useful conceptual tool for understanding tropical circulation.

In the simplest sense, the Hadley cell is still the meridional overturning circulation described by Hadley in 1735 but constrained to the tropics so that flow near the surface is equatorward and flow near the tropopause (at a height of approximately 15–17 kilometers in the tropics) is poleward. The poleward extent of the Hadley cell is governed by the position of the subtropical high-pressure belt, or, more appropriately, a broken belt of semipermanent high-pressure systems, which are located, on average, near 30° N and 30° S of the equator. Due to the Coriolis force described above, the near-surface air flowing equatorward from the subtropics is deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, resulting in the Northeast and Southeast trade winds, respectively. Similarly, the poleward transport aloft is deflected, and it combines with the converging midlatitude flow, resulting in the formation of a subtropical jet stream at the poleward edge of the Hadley cell. The Hadley cell in each hemisphere is completed by rising motion within the equatorial low-pressure belt that results from intense solar heating and convergence of Northern Hemisphere and Southern Hemisphere trade winds and sinking motion in the subtropics.

The zone of convergence near the thermal equator at the surface is known as the Intertropical Convergence Zone (ITCZ), or equatorial low. It is recognizable on satellite imagery as a bright band of clouds near the equator. The release of latent heat due to the condensation of water vapor within the ITCZ is a major source of energy for the rest of the Hadley cell circulation. Outside the
ITCZ, there is little cloud development with the Hadley cell. Instead, the region between the ITCZ and subtropical highs is characterized by warm, subsiding air. This phenomenon results in a temperature inversion, where cooler air near the surface lies below the warming, sinking air. This is known as the trade wind inversion since it occurs in the region above the surface trade winds. The result is that many areas of the tropics experience conditions where the atmosphere is very humid but precipitation amounts are low. This also means that precipitation receipt in the tropics and subtropics is largely determined by the position of the ITCZ. Indeed, seasonal movement of the ITCZ in response to variations in solar energy received produces the strong seasonal variations in precipitation that are experienced within the tropics, and especially within the subtropics. For example, in July the ITCZ’s greatest poleward position is over Northern India, where its interaction with the Himalayas plays an integral role in the summer monsoon rains. Such variations in the poleward position of the ITCZ also vary longitudinally due to surface (land/water) variations. Generally, the ITCZ will extend farthest poleward over land in the summer hemisphere. Some of the rain-producing clouds within the ITCZ exhibit strong organization and have the ability

**Figure 1** The Hadley cells are composed of rising air in the heart of the tropics and sinking air in the subtropics.

*Source: NASA.*
to intensify. These clouds are generally oriented in North-South bands that migrate from east to west, known as easterly waves, and are often precursors to tropical cyclones in the Atlantic Ocean.

The sinking motion on the poleward edge of the Hadley cell is manifest as several semipermanent (i.e., varying in position and intensity but always present) high-pressure systems, including the Bermuda High and the Pacific High. The mean position of the subtropical high-pressure belts is also consistent with the location of subtropical deserts. The sinking motion at the poleward edge of the Hadley cell inhibits the development of clouds and precipitation, keeping these regions dry.

Within the context of the global atmospheric circulation, the Hadley cell is critical for energy transfer from the tropics, where vast amounts of energy are received throughout the year, to the middle and upper latitudes, where the amount of energy received is more variable. Outside the tropics, further transport is governed primarily by transient weather systems, such as midlatitude cyclones and anticyclones. The Hadley cell circulation also influences weather and climate in other parts of the world. For example, the Bermuda High is often an important steering mechanism for Atlantic tropical cyclones entering the extratropics.

Due to the far-reaching influence of the Hadley cell circulation, there has recently been great interest in understanding both historical and possible future changes in the Hadley cell. There has been some observed evidence of a strengthening Hadley cell during winter since 1950, which has been partly attributed to both ocean warming and changes in the frequency and magnitude of El Niño events. Recent studies conducted with both observations and coupled climate models indicate a potential widening of the Hadley cell, resulting in a poleward shift in the subtropical high. Such changes should be closely monitored since variations in the location and intensity of drought are likely to result.

Justin T. Schoof

Further Readings


Torsten Hägerstrand was a Swedish geographer who made enormous contributions to human geography. The work that initially established his international reputation and his place as one of the most renowned human geographers of the 20th century concerned the study of population movements over time, the diffusion of innovations, and the behavior of individuals in space and time. Innovation indeed well describes his role in geography, in perhaps four ways: first, the introduction (at least to geography) of the idea of spatial and space-time processes, that geographic development over time could be understood and modeled; second, the particular process of spatial diffusion; third, the technique of Monte Carlo simulation; and fourth, the idea that individual behavior, not just that of large groups, could be modeled temporally and spatially. All were revolutionary. And underlying all these was the conviction that geography could offer integrated perspectives, transcending the boundaries of the humanities and sciences. His early work already insisted on the necessity of construction of theory and the responsibility of testing and evaluating empirical evidence.

Hägerstrand was born in Moheda, Sweden, and was perhaps destined to become a geographer: Even as a child, he explored and mapped his surroundings! He moved to Lund in 1937, where he studied, taught, conducted research on
migration, and completed his licentiate in 1947. In this period, he was profoundly influenced by Edgar Kant (a refugee from the University of Kartu in Estonia) in the role of theory and method in scientific geography. His PhD dissertation was completed in 1953 but was not translated into English until 1966, by Alan Pred as *Innovation Diffusion as a Spatial Process*. This work was unabashedly theoretical and quantitative, when geography in the United States and in the United Kingdom was almost universally idiographic. In 1957, his extended article (based on the licentiate research) “Migration and Area” was published in English, also a pioneering and brilliant contribution to the analysis of migration. But it was not until 1959, at the urging of Bill Garrison, that the University of Washington invited Hägerstrand as a visiting professor. The students, budding exponents of a theoretical and quantitative geography, were excited and inspired by the novelty and brilliance of his ideas, which led to a rapid and enthusiastic dissemination of innovation diffusion theory and methods. The process was furthered by the success of the Lund Symposium in Urban Geography in 1960 and by Hägerstrand’s participation in the National Science Foundation Quantitative Methods workshop at Northwestern University in 1961.

Although Hägerstrand’s approach was theoretical, quantitative, and devoted to formal modeling, it differed from the dominant early work derived from spatial economics in four basic, indeed revolutionary ways: (1) his goal was to understand spatial processes unfolding over time; (2) the unit of study was the individual or household, not population per se; (3) the processes studied were more social and cultural than economic; and (4) this required probabilistic rather than deterministic mathematics. The spatial diffusion framework has had enormous subsequent influence within geography and beyond (communications, history, epidemiology, anthropology, even economics). Within geography, perhaps the most influenced was Allan Pred, who translated Hägerstrand’s dissertation and did work on urban diffusion and later time-geography. The evaluation of spatial diffusion also required advances in spatial statistics.

Although Hägerstrand was a prominent regional scientist, and indeed president of the European section of the Regional Science Association in 1968–1969, he critiqued much of regional science work as too mechanistic and uninformed by actual human individual and social experience, as exemplified in his famous article “What About People in Regional Science?” published in 1970. Indeed from this date on, his extended collaboration with Anne Buttimer led to the devotion of much time and effort in teaching and writing to the integration and compatibility of the theoretical and quantitative with the social and humanistic.

A major second advance in theory and methodology came in the 1970s with Hägerstrand’s work in time-geography, which again influenced many researchers within and outside geography and was viewed by Hägerstrand as his major contribution. Time-geography maps, three dimensionally, the trajectories (of sets) of individuals, considering the opportunities, constraints, and conditions required for meeting. Important subsequent work includes that of Allan Pred and Nigel Thrift. Time-space conceptions are valuable from both theoretical and practical viewpoints, for example, with respect to urban traffic, accessibility, and social networks. In later years, these original interests expanded to reflections on technology and society and a broader concern with urban and regional planning and sustainability.

Hägerstrand was honored by a set of essays dedicated to him in 1981 and by a posthumous appreciation in *Progress in Human Geography*. In the course of his long and fertile career, he received numerous awards, including honorary doctoral degrees from the Universities of Glasgow (1971), Edinburgh (1974), and Bristol (1985); Ohio State University (1985); and the Norwegian School of Economics (1986). He was awarded the Charles P. Daly Medal of the American Geographical Society (1966), the Outstanding Achievement Award of the Association of American Geographers (1968), the Vitus Bering Medal of the Danish Geographical Association (1970), the Anders Retzius Medal of the Swedish Society for Anthropology and Geography (1973), the Victoria Medal of the Royal Geographical Society (1979), and *Lauréat d’Honneur* of the International Geographical Union (1984). He was a member of the Royal Swedish Academy of Sciences; the Royal Academy of History, Letters and Antiquities; and the Royal...


Peter Haggett is one of the world’s preeminent geographers and professor (now emeritus) of urban and regional geography in the School of Geographic Sciences at the University of Bristol. His fame rests on major contributions in three scientific areas: (1) the nature of geography as a discipline, (2) quantitative methods and location analysis in geography, and (3) the geography of infectious diseases, in particular the analysis of epidemics.

He was born in rural Somerset and took his undergraduate studies at St. Catherine’s College, Cambridge, graduating “double first” in 1954. He first taught at University College, London, in 1957, returned to Cambridge from 1957 to 1966, and then went to the University of Bristol, where he taught until his retirement in 1995. He was a visiting professor in many countries, but especially in the United States, Canada, and Australia. He has received many awards and honors, including the ones from the Royal Geographical Society and the American Geographical Society, the Anders Retzius medal (Sweden), Vautrid Lud prize (France), and the Laureat d’Honneur of the International Geographical Union. He has received six honorary degrees and also served as the vice chancellor of his university and as the vice president of the British Academy.
Haggett is the author or editor of more than 30 books, emphasizing geographic practice theory and methods in the earlier part of his career and the study of epidemics and the distribution and spatial relations of infectious diseases in the latter half. Along with Richard Chorley, he was a British pioneer of the “quantitative revolution,” and his famous and revolutionary book, *Locational Analysis in Human Geography*, was published in 1965, preceding the earliest American texts. This volume was followed by additional books on models and spatial theory: *Network Analysis in Geography* in 1969, *Elements of Spatial Structure* in 1975, *Locational Analysis* in 1977, and *Locational Methods* in 1977.

In the broader area of geography as a scientific discipline are more influential books, most especially *Geography: A Modern Synthesis* (1972), with three subsequent editions and six translations; *Models in Geography* (1967), with Richard Chorley; *The Geographer’s Art* (1990); and *Geography: A Global Synthesis* (2001). With his Cambridge colleagues, he established two preeminent journals, *Progress in Physical Geography* and *Progress in Human Geography*.


Richard Morrill

See also Diffusion; Medical Geography; Quantitative Revolution

Susan Hanson is one of the most accomplished academics in U.S. geography today. During her long and productive career, she became a major researcher of urban labor markets and urban transportation and a founder of American feminist geography. Her accomplishments are also widely recognized. A past Guggenheim Fellow, she is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. Hanson is the first female geographer elected to both academies in 2000.

Hanson’s half-century-long career in geography began once she discovered the field as an undergraduate student in Middlebury College (1960–1964), thanks to an outstanding geography professor. After spending several years in Kenya as a Peace Corps volunteer, she earned a PhD in geography from Northwestern University (1967–1973). After earning tenure at the University at Buffalo, where her position was split between the departments of geography and sociology (1972–1980), she moved to Clark University (1981), where she spent the rest of her career. There she currently holds the title of research professor. She chaired Clark’s School of Geography for long periods and held prominent national leadership positions, including that of president of the Association of American Geographers.

Susan Hanson has been exceptionally productive. To date, she has authored and edited 7 books, contributed more than 70 articles and commentaries to peer-reviewed journals, and written more than 30 book chapters and more
This prolific work has focused on gender and work, travel activity patterns, feminist approaches to scholarship, and the importance of gender as a category of analysis. It has had a profound impact and has shaped today’s geography in fundamental ways.

Hanson’s edited volume on the geography of urban transportation is now a classic text in its third edition. Her numerous articles on gendered local labor markets as well as the related book *Gender, Work, and Space* (1995), coauthored with Geraldine Pratt, are central texts in feminist geography. Contrary to traditional geographic approaches to work that assumed the agency of an “economic man” and were gender blind, Hanson’s research showed that people make decisions about work not in isolation from but in direct relation to their domestic responsibilities. Since women shoulder most domestic responsibilities, local labor markets also become segmented along gender lines, and women have shorter commuting times and lower-paid jobs.

Hanson’s scholarship pioneered not only new research directions but also the ways geographers go about doing their research. Trained as a quantitative geographer, Hanson infused the prevailing quantitative geographic methodologies with feminist sensibility. On many occasions, she called for considering difference that not only includes gender but also extends to class, race, and sexuality. Her research began combining the traditional disciplinary focus on empirical work with the pathbreaking feminist theory of the time. Hanson also opened the door to mixed-methods research by using quantitative and qualitative methods together. And she advocated for bringing feminist reflexivity in all kinds of academic practice, including research, teaching, mentoring, and service.

Yet at the core of her university work is a commitment to her students, whom she views as both a major responsibility and a source of inspiration. Throughout the years, Hanson has advised dozens of undergraduate students and more than 20 PhD students and has served as a mentor to many more.

Despite a successful career, Hanson describes herself as an “accidental academic,” a concept in line with feminist rethinking of women’s working lives as nonlinear and often improvisational.

This is evident in the context of a career that spans and contributes to the profound shift in academic geography from a male-dominated field to the more diverse discipline today. Hanson’s career and life will continue to inspire female college students and those who choose a career in academia.

*Marianna Pavlovskaya*

See also Commuting; Feminist Geographies; Feminist Methodologies; Gender and Geography; Transportation Geography

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**Further Readings**


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**Harley, Brian (1932–1991)**

James Brian (J. B.) Harley was a historical geographer and a key figure in the contemporary field of the history of cartography. He helped lay down some of its main theoretical foundations and ideas on how to look at maps and helped structure and expand the discipline as well. Central to his contribution was his conception of the map as a social and not simply a technical construct. As exemplified by his *Maps and the Columbian Encounter*, published in 1990, using notions from
postmodern literary criticism and from the history of art, he especially scrutinized maps for their “hidden agendas” and “silences” and other biases that directly reflect the values of their creators and the times of their creation. He fervently advocated the study of maps within their social and cultural contexts.

Harley was born on July 24, 1932, in Bristol, England. He attended Brewood Grammar School in Staffordshire, and after graduation, he served for 2 years in the British Army in Cyprus, Egypt, and Trieste. Thereafter, he majored in geography and minored in history at the University of Birmingham, receiving his PhD in 1958. In the same year, Harley was appointed to an assistant lectureship in geography at Liverpool University in 1958 and a lectureship at the University of Exeter in 1970, where he became the Montefiore Reader in Geography in 1972. In 1976, he became a professor of geography at the University of Wisconsin, Milwaukee, and director of the Office of Map History at the university’s Golda Meir Library, which contains the map collection of the American Geographical Society. For his scholarship, Harley was awarded a Doctor of Letters from Birmingham in 1985 and the silver medal of the British Cartographic Society in 1991. He died of a heart attack on December 20, 1991.

While in Liverpool, Harley turned to the history of cartography. He was influenced early on by Harry Thorpe and R. A. Skelton. His first work in the field was *Christopher Greenwood, County Map-Maker*, published in 1962. It was followed by the valuable *Historian’s Guide to Ordnance Survey Maps* in 1964 with C. W. Phillips. In addition to continuing work on the Ordnance Survey, Harley published *Mapping the American Revolutionary War* in 1978 with Barbara Petchenik and numerous articles in *Imago Mundi*, *Cartographica*, and the *Geographical Journal*, among others. In 1977, with David Woodward from the University of Wisconsin, Madison, Harley conceived and collaborated on the monumental six-volume *History of Cartography*, the first three volumes of which were published in five large books in 1987, 1992, and 2007. It is not only becoming the foundational reference work, but it is also profoundly influencing the entire field.

**Dennis Reinhartz**

See also Cartography; Cartography, History of; Critical Human Geography; Historical Geography

### Further Readings


### Hartshorne, Richard (1899–1992)

Richard Hartshorne was an influential early- and mid-20th-century American geographer, best known for his aggressive promotion of chorology as the optimal way of examining landscapes and spatial distributions.

Born and raised in Pennsylvania, he became a math major at Princeton University, completing his degree in 1920 after serving in World War I. Hartshorne then earned a PhD from the University of Chicago in 1924, taking courses from Ellen Semple, J. Paul Goode, and social ecologists such as Harlan Barrows. He was greatly influenced by Alfred Hettner, who led him into neo-Kantian ideas and views of space and, to a lesser extent, environmental determinism. At the University of Minnesota (where he taught from 1924 to 1940) and the University of Wisconsin (where he taught from 1940 to 1970), Hartshorne published early works on the agricultural, urban, and economic landscapes of the Midwest and worked on the political geography of Eastern Europe in the 1930s. He served as president of the Association of American Geographers in 1949.

Greatly influenced by Immanuel Kant and Alfred Hettner, he strongly advocated for chorology as the heart of the discipline. Essentially, his
view was that geography, like history, is a synthetic, not analytic, discipline that seeks to find relations among variables through their proximity in space. Regions thus played a role in Hartshorne’s conception analogous to that of periods in the historian’s schema. This idea was most fully developed in his famous book, *The Nature of Geography*, published in 1939, a landmark book in the discipline’s 20th-century history. Hartshorne’s view centered on what he called “areal differentiation,” which he saw as unique to the discipline and the basis of its identity within the academic division of labor. Regional geography, therefore, was the heart and soul of the discipline. By combining vast numbers of human and physical elements in unique ways, regions simultaneously overcame the ancient schism between human and physical geography (much like the studies of the land—*pays*—by Paul Vidal de la Blache) and created unique identities that could not be easily understood in a lawlike, scientific manner.

Hartshorne fully acknowledged the complexity of the world and maintained that regions, which are relatively homogeneous units by definition, could be more easily understood individually and, when accreted into larger groups, provided a glimpse into the world’s geographies. He raised the important question as to what constitutes a region and what its significance is. Following Kant, he held that regions are not “natural” entities but purely mental constructs, that is, real in their ontological significance only as categories that humans impose on the world to simplify it. Like models, regions are tools that allow people to gain an understanding in the world only by sacrificing some detail. Hartshorne’s view has often been oversimplified as crude spatial determinism, in which location is a substitute for explanation and proximity is equated with causality. Indeed, in many preindustrial societies with high degrees of friction of distance and distance decay, this view maintains a certain plausibility.

More radically, Hartshorne maintained that geography should satisfy itself with regions and held that there was little need to pursue explanatory laws, which he wrote off as “science,” not geography. “Science,” in this reading, was concerned with generalization, while geography, as a synthetic discipline, was concerned with the unique. Additionally, because landscapes are relatively stable from the perspective of individual life spans (at least, the preindustrial landscapes on which he focused were), he held that there was little need to study their change over time: Geography should be the examination of frozen patterns and should be content with forms and appearances without venturing into the analysis of causal processes. This view reflected Hartshorne’s deeply held empiricism: Only by sticking to the data—to the “facts” as given entities—could geographers come to know the real world. Similarly, he had a healthy respect for cartography.

Hartshorne’s worldview, like empiricist chorography in general, collapsed in the 1950s as the discipline began its shift into logical positivism. In particular, a famous, stinging rebuke by Fred Schaefer in 1953 criticized his “exceptionalism,” the notion that history and geography were only concerned with the unique. Schaefer held that all sciences were concerned with uniqueness to one extent or another. Moreover, simply classifying data on the basis of regions ignored the vital role of processes, a stance that confined geography to an “immature” status. Rather, geographers should seek out explanatory, nomothetic laws. The division between advocates of the idiographic and the nomothetic, between empiricists and those who took theory seriously, became full blown.

Hartshorne never fully recovered from what he perceived to be both a professional and personal attack that he felt oversimplified, distorted, and selectively interpreted his views. In an attempt at a rebuttal, he wrote *Perspectives on the Nature of Geography* in 1959. However, he did back off from his original claim that regions were the penultimate geographic product and claimed that he was never opposed to laws, or, as he called them, “generic concepts,” and that geography was always simultaneously nomothetic and idiographic.

Barney Warf

See also Chorology; Empiricism; Hettner, Alfred; Human Geography, History of; Idiographic; Kant, Immanuel; Regional Geography; Regions and Regionalism; Vidal de la Blache, Paul
David Harvey is perhaps the most influential contemporary human geographer in the world. Over several decades, he played a role in the quantitative revolution, but in the early 1970s, he was the seminal figure in the introduction of Marxism into the discipline. In a long series of highly influential books, he has steadfastly advocated on behalf of social justice and offered biting critiques of capitalism, neoliberalism, inequality, and oppression in all its forms.

Born in Gillingham, Kent, England, his initial interest in geography, he has said, came from his early desire to run away from home and see the world. He has certainly done that, both in his academic career and at internationally diverse public speaking engagements. His university training was at Cambridge University, where he received his PhD in 1961. It was at Cambridge that he became involved in new theoretical debates in the discipline concerning the scientific status of geography. Harvey’s dissertation, while seemingly a traditional historical geography of the regionally unique hop cultivation in Kent in the 19th century, reflects this debate as it tries to come to theoretical terms with the causal processes of change leading to the different forms that that cultivation assumed.

After Cambridge, Harvey took a position as Lecturer at the University of Bristol, where he continued his pursuit of scientific geography. Anglo-American geography at the time was dominated by the belief that the object of study of geography was ultimately unique landscapes not conducive to generalization or causal covering laws. In this view, the study of geography was somewhere between the sciences and the humanities. Harvey’s cohort of new faculty set out to overturn this conceptualization of the discipline by attempting to render it closer in focus and methodology to the more established sciences.

This quest led to Harvey’s first major book, *Explanation in Geography* (1969), which broadly surveys the philosophy and methodology of science as it relates to what he considered to be the main objects of study of geography: time, space, and, most important, space-time, that is, the two dimensions sutured into an indivisible whole. The latter notion was particularly important to the overall argument because it rendered the specific object of study of geography—spatial variation—open to intersubjectively repeatable, and therefore objective, causal analysis. This book thus systematized Harvey’s concern with the intersection of process and pattern or spatial form that was embedded in his earlier work on hops cultivation in Kent.

Harvey spent nearly a decade coming to terms with how space and place (pattern, form) could be considered in a more positive, truly scientific manner, and *Explanation in Geography* is indeed considered to be a central manifesto for positivism in geography. Interestingly, however, by the time the book was published, even Harvey himself had moved beyond its main message. This shift was during the late 1960s, and social justice movements literally in the streets rendered the
ultimately ivory tower quest for “scientific rigor” much less important than making a difference in the real world. This was brought home to Harvey dramatically when he moved to the racially and class-polarized city of Baltimore to take a position at Johns Hopkins University in 1969.

His experience on the streets of Baltimore pushed Harvey to seek ways to change an unjust reality, instead of merely questing after a somehow “objective” knowledge of it. This transition in his approach is recorded famously in his second major book, *Social Justice and the City* (1973), which quickly became popular as a legitimizing narrative for those attempting to make the transition from the ivory tower to social activism. In this book, Harvey makes the transition from a liberal advocate of objective scientific planning to a socialist activist increasingly enamored with Karl Marx’s critique of capitalism as a system of exploitation and social oppression.

Harvey spent the entire next decade working out Marx’s critique of capitalism, which was scattered across literally thousands of pages of manuscript, published and unpublished. The resulting book, *The Limits to Capital* (1982), is an attempt to work through Marx with a specific focus on how to theorize capitalist space-time on the basis of Marx’s critique, which largely ignored the theoretical, and ultimately political, importance of spatial variations in social relations. Yet *The Limits to Capital* was published at a time when many on the political left were moving away from Marxism, and as a result, its message was not much studied, much less understood. This change was brought home to Harvey as a result of another personal relocation, this time back to England in 1987 to take up the Halford Mackinder Chair of Geography at Oxford University. In England, particularly, what was considered to be Harvey’s rigorously orthodox Marxism seemed passé to many post-Marxists and others at the time.

Yet Harvey has argued that *The Limits to Capital* is one of the most important of his many works, if not the most important. All the books that follow *The Limits to Capital* are informed by its careful working out of the limits to Marx’s critique of “capital” and to capitalism itself. Harvey fully adopts Marx’s dialectical materialist critique of the processes of capitalism while extending its critical insights to the production of ever-evolving patterns of capitalist space-time. The latter involves what Harvey calls a “spatial fix,” which Marx largely ignored but which has been absolutely necessary for the survival of capitalism, now increasingly global in scope.

After two books on urbanization, published in the mid 1980s, which provide significant empirical corroboration of the theory worked out in *The Limits to Capital*, Harvey’s next major book, *The Condition of Postmodernity* (1989), became his most popular by far, selling more than 100,000 copies and translated into several languages. *The Condition of Postmodernity* established Harvey as a transdisciplinary scholar, and yet, according to him, it was a book that seemed to literally fly off his pen. It is worth dwelling on this book because it helps characterize all his subsequent works. *The Condition of Postmodernity* was conceived as a written response to his many post-Marxist critics. It successfully theorized, in a systematic Marxist way, the apparently unsystematic (some said “unorganized,” others “postmodern”) empirical nature of capitalist society toward the end of the long postwar boom. Harvey thus fashioned a quite unfashionable Marxist “master narrative” of postmodernity, explaining in very clear prose the systematic processes behind apparently unrelated patterns of events in architecture, social relations, urban politics, social theory, and so on. This perspective allowed for a more holistic grasp of what seemed to be the wholly unrelated movements and events of the oft-celebrated “postmodern.”

by the theory worked out so difficultly in *The Limits to Capital* and yet expressed so eloquently in *The Condition of Postmodernity*.

Harvey eventually returned to Johns Hopkins in 1993 and moved on to the City University of New York in 2001, where he holds the title of distinguished professor in the department of anthropology. He continues to write and speak prolifically and now has a small corpus of works written about him.

*Kevin Archer*

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**Further Readings**


Postmodern and poststructuralist perspectives continue to strongly influence the humanities and social sciences, revealing unequal power relations between those social groups at “the center” of society and those who traditionally exist at the “margins.” Human geographers are particularly concerned with revealing how notions of place, geographical scale, territorial claims, and social space are implicated in the construction of these “center-margin” identities. Much of this research has focused on the geographies of “race,” gender and sexuality, ethnicity, disability, and other “marginalized” identities that tend to place these groups “outside” long-constructed “norms” of Anglo-American society (usually represented as mostly male, white, Christian, and heterosexual). This leads to various social “border” constructions, thereby “defining” who is “in place” and who is “out of place.” While uncovering the processes by which racial, ethnic, and sexual minorities have been marginalized, human geographers have explored how those “inside” societal norms have constructed these boundaries and how they work to maintain them. At the extreme end are those who passionately believe that North America and Europe represent the last remaining bastions of white, heterosexual, Christian society and actively work to keep it so. This stance has given rise to various “hate groups,” who obsess over their conceptions of what is “normal” within society and what is not.

Through speeches and rallies, publications, social networks, and the extensive use of the Internet, hate groups construct and enforce imaginary social boundaries through threats, intimidation, and at times violence. In the United States, hate groups have included members of the American Patriot and Christian Identity Movements, neo-Nazi groups, and the Ku Klux Klan. The election of an African American president in 2008, combined with a worldwide economic downturn, has also led to an increase in domestic hate group activity. Studying the geographies of hate includes mapping the spatial distribution and extent of hate groups (the Southern Poverty Law Center in Montgomery, Alabama, is the leading tracker of hate groups in the United States).
States), revealing the geohistorical contexts in which these groups exist and thrive, and examining how hate groups use geographic concepts such as scale, place, borders, and territoriality to further their agendas by excluding certain people from their social spaces.

The neo-Confederate movement provides one example of the geographies of hate. Based on romanticized visions of the Civil War and ante-bellum southern society, neo-Confederates have constructed and mythologized their vision of the American South as a culturally cohesive white, heterosexual, Christian nation directly descended from immigrants hailing from the Celtic areas of the British Isles and especially Scotland. By definition, such a conceptualization excludes African Americans, gays and lesbians, and non-Christians from the region. Indeed, neo-Confederates support secession from the United States to create (or, in their minds, preserve) the purity of their “nation.”

In addition to hate group activity in the United States, hate groups are proliferating worldwide. Countries such as the United Kingdom, France, and Germany have seen a steady rise in hate group activity, partly because of resentment toward the immigration of foreign-born labor resulting from the processes of global capitalism. The Baltic States and Russia have seen the rise of neo-Nazi skinhead groups who target sexual and ethnic minorities with intimidation and violence. Perhaps the most horrific example of hate group activity exists in places such as Bosnia, Rwanda, and Sudan, where ethnic, nationalist, and religion-based movements have resulted in ethnic cleansing and genocide in recent decades.

Jonathan Leib

See also Emotions, Geography and; Ethnocentrism; Fear, Geographies of; Identity, Geography and; Race and Racism; Whiteness

Further Readings


population, Germany needed greater amounts of land and resources for its state and people to survive and thrive in international competition with other states, advocating that Germany take over all or parts of adjacent states and other territories. He also proposed a division of global space into three giant blocks or pan-regions: (1) the Americas (centered on the United States), (2) Europe and Africa (centered on Germany), and (3) East/southeast Asia and Australia (centered on Japan). At the same time, borrowing from the Mackinder tradition, Haushofer saw the global geopolitical picture as a competition between land-based and sea-based powers. Early in World War II, Haushofer argued that Germany's lebensraum could best be achieved through the creation of a “heartland” alliance with the Soviet Union and Japan against the maritime-oriented British Empire.

Haushofer’s vision of an expansionist Germany fit well with Nazi war aims. Haushofer’s connections to the Nazis came through his former student Rudolf Hess, who he first met in the late 1910s and then later taught at the University of Munich. Haushofer visited Hess and Adolph Hitler in prison after the two were arrested for the failed 1923 Munich Beer Hall Putsch. Through these connections, some saw Haushofer’s (and, by extension, geopolitics’) influence in passages in Hitler’s Mein Kampf. While more recently geographers have questioned the extent of Haushofer’s influence on Hitler and the Nazis (whatever influence he had ended in 1941 following both Hess’s flight to Britain and the German invasion of the Soviet Union, in direct contradiction to Haushofer’s “geopolitical” advice), the American establishment’s need to create a “boogeyman” during World War II to explain Hitler’s actions centered on Haushofer and his supposed “Institute of Geopolitics” (which did not exist) masterminding Nazi war strategy (as seen in articles in American magazines such as Life, The New Republic, and Reader’s Digest and in a 1943 Academy Award–nominated short documentary, Plan for Destruction).

Following the end of the war, Haushofer was interrogated but not charged with war crimes. Instead, he and his wife committed suicide in 1946. Even though geopolitics continued to be practiced by foreign policymakers and analysts in the decades after World War II, the popular connection between geopolitics and the Nazis led to geopolitics falling out of favor as an academic field of study until the 1980s.

Jonathan Leib

See also Geopolitics; Human Geography, History of; Political Geography

Further Readings


Ferdinand Vandeveer Hayden, American geologist and paleontologist, was a prominent figure in the scientific exploration of the northern plains and northern Rocky Mountains from the early 1850s to the 1880s. His writings made important contributions to Earth science and also helped familiarize the American public with the scenic wonders of the West.

Born in Westfield, Massachusetts, and raised by relatives in rural upstate New York, Hayden was largely self-made as an Earth scientist. He worked his way through Oberlin College and then studied at Cleveland Medical School and Albany Medical College, which awarded him an MD in 1853. Yet his medical activity was limited to service as a Union Army surgeon during the Civil War. Well before the war, he had become an active field researcher in geology and paleontology, and he returned to them when hostilities ceased.
In Albany, Hayden joined a group of young followers of James Hall, the state geologist of New York. Hall encouraged Hayden to accompany another Hall protégé, Fielding Bradford Meek, to the Dakota badlands in 1853 to collect fossils. After this initial trip, Hayden returned to the northern plains for two more years, working sometimes on his own and sometimes with Meek, who concentrated on the paleontological aspects of their work. Hayden’s skill was in rapid geologic reconnaissance—accurately inferring the underlying structure of large areas from widely separated outcrops. Later in the 1850s, Hayden served as a geologist on three more expeditions to the upper Missouri valley. These required considerable enterprise on Hayden’s part since there was as yet no sustained and consistently funded program of natural history exploration in the West. Hayden established the stratigraphy of the upper Missouri valley and in the process discovered the remains of extinct megafauna such as camels, horses, and members of the elephant family.

After his wartime medical service, Hayden accepted a professorship at the University of Pennsylvania; yet he continued to spend much of his time in the West. Hayden’s survey is now funded by an annual appropriation from the Department of the Interior and has produced a voluminous body of annual reports, bulletins, and miscellaneous publications. This corpus indicates the height of Hayden’s national prominence as a public scientist. Along with his solid contributions to geology and paleontology, he was a popularizer and wrote promotional works that helped “sell” the Rocky Mountain West to Easterners as a land of scenic grandeur. He included the prominent landscape photographer William Henry Jackson in his expeditions of the 1870s. Such efforts helped establish the Yellowstone National Park and familiarized the public with the cliff dwellings of Mesa Verde.

Political pressures in Washington forced the coordination of the multiple western surveys under the U.S. Geological Survey (USGS) in 1879. Hayden was a leading contender for the directorship of this new agency but was outmaneuvered by his rivals Clarence King and John Wesley Powell. King became the first head of the USGS and was followed by Powell 2 years later. Hayden was sidelined, though he continued his fieldwork in the West. Failing health forced him to resign from the USGS in 1886, and he died the following year.

Thomas Frederick Howard

See also Physical Geography, History of; Powell, John Wesley; United States Geological Survey (USGS)

Further Readings


**HEALTH AND HEALTH CARE, GEOGRAPHY OF**

The geography of health and health care explores how and why people’s health and access to health care vary from place to place. Health is typically defined as a positive quality that encompasses social, physical, and emotional well-being and not merely the absence of disease. Health care comprises diverse activities—personal, social, and institutional—for maintaining and promoting health. Formal health care is provided by trained professionals in organized settings such as hospitals and clinics. Informal care is provided by family and community members.

The uneven geographies of health and health care have profound implications for individual and societal well-being. These geographies are of particular interest within the field of medical geography and the broader but closely related field of health geography. This entry discusses several key themes in research on the geography of health and health care.
Geographic health inequalities refer to disparities in health from place to place. Such inequalities are apparent at all spatial scales—from the global to the local. At the global scale, indicators such as infant mortality and life expectancy show vast differences in population health between high-income and low-income countries. In 2008, estimates of life expectancy by country ranged from 82 yrs. (years) in Japan to 33 yrs. in Swaziland (Figure 1). Poverty, lack of clean water and sanitation, inadequate food supply, political and cultural unrest, contact with environmental and infectious disease hazards, and lack of medical treatments and facilities create significant barriers to population health in many low-income countries. Some countries in Southern Africa have seen a decrease in life expectancy in recent decades tied to political and economic upheavals and the spread of HIV/AIDS. Declining health and longevity create potent barriers to economic and social development.

The health transition model (epidemiological transition) describes the typical changes in health indicators as places undergo economic development. According to the model, improvements in economic development are associated with increasing life expectancies and general improvements in health. There is also a shift in the causes of death from communicable diseases and malnutrition to degenerative and humanly created diseases. Degenerative diseases include conditions such as heart disease and cancer, which involve impairment of organs and tissues. Humanly created conditions are related to occupational and environmental exposures and risk behaviors that are by-products of economic development. As industrialization occurs and incomes rise, public health investments, improvements in diet, and access to health care lead to reductions in deaths from infectious diseases. At the same time, longer life spans, exposures to industrial and occupational hazards, and increases in smoking, overnutrition, and other risk behaviors heighten the risk of death from degenerative and humanly created diseases. Although the health transition model holds quite well overall, it does not account for the diversity in health outcomes among countries at similar stages of economic development. Health geographers have shown how social, political, and historical conditions in different places influence their varying health transitions.

**Figure 1** Life expectancy (years) by country, 2008

Physical Features of the Environment | Climate, Topography, Biota, Air, and Water
--- | ---
Availability of healthy environments at home, work, and play | Quality of housing, employment opportunities and hazards, environmental hazards
Services | Education, health and welfare services, policing, transportation
Sociocultural characteristics | Opportunities for social interaction, religious and cultural organizations, norms and values, crime
Reputation of community | Perception of area by residents, government officials, lending agencies; place attachment

Table 1  Contextual factors that influence health

Source: Adapted from MacIntyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? Social Science & Medicine, 55, 125–139.

Geographic Health Inequalities: Regional and Local

Health inequalities also exist at the regional scale, often corresponding closely with disparities in class, income, race, and ethnicity. Poor health is strongly associated with economic and social disadvantage: Poverty, lack of education, and social or cultural marginalization increase the risk of ill health. Evidence shows that poor health is tied not only to absolute disadvantage but also to relative disadvantage as reflected in income inequality. Living in a place with a highly unequal income distribution can pose a health risk. Geographic research shows that in places such as the United Kingdom, health inequalities have increased in the past decade, reflecting the widening gap in incomes between the rich and the poor. Strong ties between economic deprivation and health are also evident in large cities in the United States, where we find exceptionally poor health indicators in impoverished inner-city neighborhoods.

The causes of regional and local health inequalities can be grouped into two broad categories: (1) composition and (2) context. “Composition” refers to the socioeconomic and demographic characteristics of populations, such as age, race/ethnicity, and poverty. “Context” describes the characteristics of the places in which people live and interact, including environmental hazards, crime, housing characteristics, and the quality and availability of services, social networks, cultural resources, and employment opportunities (Table 1). Contextual factors affect a wide range of health concerns from infant mortality to cancer to injury. Obesity, for example, is associated with contextual factors such as the availability of grocery stores and fast-food restaurants, the “walkability” of neighborhood environments, the availability of parks and recreation facilities, and perceptions of crime and safety. To unravel the significance of contextual and compositional factors in affecting particular kinds of health risks, researchers are using multilevel modeling methods that assess the impacts on health outcomes of variables measured at different geographical scales.

There is a growing recognition of the interrelations between composition and context. Not only are the social and economic characteristics of people closely tied to the characteristics of the places in which they live, but also some populations are more vulnerable to health-related environmental exposures. Place characteristics strongly affect the health of the elderly and the poor, who are more dependent than others on the resources in their local communities. The roles of context and composition have been widely debated, and today most health geographers agree that it is the interrelationships between people and places that give rise to health inequalities.

Health and Place

Since the early 1990s, the concept of place has played a central role in our understanding of the geographies of health and health care. Place is a relational concept that describes how people interact with and experience the environments in
which they live. Places are environments infused with meanings. Places vary greatly in size, from the personal space of a room to the vast space of a country or continent. Health geographers study how people’s experiences and sense of place affect health and how people and institutions create healthy and unhealthy places.

Therapeutic landscapes, places perceived as beneficial for health, are critically important in current understandings of health and place. These landscapes include culturally defined places of spiritual, emotional, or physical healing, such as Lourdes in France. They also include places with distinctive environmental qualities, such as mineral springs, or topographic features that are thought to promote health and healing. Other places focus on religious structures, such as temples. In visiting these sites, people may experience a “transformation to wellness” through their interactions with the landscape and their social interactions with other visitors. In every case, these therapeutic landscapes reflect the complex layering of historical, social, and cultural relations in a particular place setting. At a more microscale, therapeutic landscapes can also be ordinary spaces, places in everyday life that promote healing and well-being. A prayer room in one’s home, a local park, or a gathering place may be a space of relaxation and healing. Places such as spas and resorts, created and operated by business firms, are commercialized therapeutic landscapes. Increasingly important to local economies, these sites represent the uneasy ties between therapeutic and commercial goals.

Unhealthy places—landscapes marred by environmental degradation and contamination—have also attracted interest. Environmental justice describes the uneven distribution of environmental hazards among communities by race, ethnicity, and socioeconomic disadvantage. Racial and ethnic minorities and the poor often bear a disproportionate share of environmental hazards, including air and water contamination and hazardous facilities. People’s perceptions of local environmental hazards and their efforts to mobilize against them are key to understanding the impacts of unhealthy place environments. In many disadvantaged communities, people are unaware of local environmental hazards, or if aware, they lack the time and resources needed to mobilize against them. Community characteristics and sense of place also shape community members’ attitudes toward environmental hazards. When people feel a strong attachment to a place, they are likely to resent and oppose environmental threats, whereas those with weaker ties to their residential neighborhoods are less likely to mobilize against such threats.

**Geography of Formal Health Care**

Formal health care services have distinctive geographies from the global to the local scales. The geography of health care describes spatial variation in the locations, numbers, and types of services. Health services are often divided into three levels: (1) primary-care services that address routine health needs, (2) more specialized secondary services typically offered in hospital settings, and (3) highly specialized tertiary services provided only in the most advanced hospitals. Of the three, primary services are the most numerous and widely distributed over the landscape. Tertiary services are offered at a limited number of highly specialized hospitals, mainly located in large metropolitan areas.

The location of health services is important because people’s use of health services is highly localized. Distance strongly affects the choice of service providers: People are less likely to use services located far away from home. This distance decay relationship arises because of the time, cost, and effort involved in traveling long distances and people’s lack of familiarity and comfort with faraway services. The negative effect of distance on utilization varies across health services: Primary-care services such as routine medical checkups and dental care exhibit a steeper decline in use with distance than do tertiary services. Population characteristics also affect distance decay. People with low incomes and limited mobility are much more reliant than others on health services located close to home.

The territorial organization of formal health care is significant in several respects. Health care providers typically serve a geographically defined catchment area from which they draw most of their clients. Catchment areas reflect not only distance but also the locations of competing providers and the characteristics of the health
care facility, including quality and cost of services. Some health providers have particular ethnic, religious, or linguistic affiliations, attracting patients from long distances who prefer those affiliations. Publicly funded providers may have a politically defined catchment area. Like other economic and social organizations, health providers often act strategically to shift their catchment areas and patient populations. In the United States, large urban hospitals have established satellite facilities in profitable suburban locations. The ties between health care providers and local communities also have implications for the costs and nature of the services provided. Costs reflect the availability and cost of labor, land, and other inputs; the kinds of services provided reflect local medical cultures and attitudes toward medical intervention. Thus, the geography of formal health care results from the complex interplay among place characteristics, provider decisions, population characteristics, and decision making.

At the global scale, there are marked differences among countries in the availability and quality of services and in how health care is provided. Medical providers, facilities, and treatments are often in short supply in low-income, developing countries. Shortages are especially acute in rural areas, economically marginalized areas, and regions with political and social unrest. Exacerbating these shortages is the migration of doctors and nurses from developing to developed countries, a “brain drain” of medical providers.

The financing and provision of formal health care also differ greatly at the global scale. In some countries, health care is primarily a public service, provided through a network of public hospitals and clinics and financed primarily by tax revenues. Access to care is universal rather than based on ability to pay. Britain’s National Health Service is a good example. In contrast, in countries such as the United States, private provision predominates: Private and nonprofit firms offer services and compete under quasi-market conditions. Although consumers’ ability to choose health providers is high, their choices may be limited by the lack of insurance and other financial barriers. Although public and private represent archetypical forms of health care provision, most countries maintain a mix of the two, with the mix shaped by national politics and historical circumstances.

At the national scale, geographical access to health services varies greatly between urban and rural areas. Health services are less available in rural areas because population numbers and densities are not sufficient to support large numbers of service providers. Rural communities often experience difficulties in attracting and retaining medical professionals. The lack of health care providers means that rural residents face long travel distances in obtaining health services and their choice of providers is limited. Poor geographical access can lead to low rates of service utilization, particularly for routine and preventive services.

An important dimension of the geography of health services is the relationship between service need and geographical accessibility. The inverse-care law describes the situation in which places with the highest need for care have fewer services available. In many American cities, the geographic distribution of primary-care services follows an inverse-care pattern. There are acute shortages of primary-care physicians and dentists in many low-income, inner-city neighborhoods. Although residents might be able to travel outside their neighborhoods for care, economic constraints, lack of knowledge of and familiarity with services in more distant neighborhoods, and sociocultural differences create barriers to travel. Therefore, many low-income urban residents rely on hospital emergency rooms for primary care.

Changes in health policy have profound implications for geographic disparities in health care. Since the 1980s, many industrialized countries (e.g., Canada and Britain) have pursued privatization of health care, with spatially and socially uneven impacts. Privatization is often associated with changes in health care delivery, including the closure of hospital and clinics in some locations. Devolution, the transfer of health care provision and administration from higher to lower levels of government and/or to informal settings, has also been widely adopted. It involves an explicit shift in the geographical scale at which care is provided. In the mental health arena, geographers have documented the geographical and social impacts of deinstitutionalization policies—policies that shifted patients from large, isolated mental hospitals to smaller, community-based facilities. Such policies represent a specific form of devolution that has profoundly affected the lives
of people with mental illness. On the positive side, patients are no longer socially and geographically isolated in large psychiatric institutions; yet many patients were released into community settings with inadequate resources and support, creating new landscapes of despair.

**Geography of Informal Care**

There is a growing interest in the geographical dimensions of informal health care—care provided in home and community settings. Worldwide, informal care accounts for the vast majority of health care provision. Geographers have studied where informal care is provided, how changing policies affect informal care, how the places in which people live affect the intensity and quality of informal care, and how people actively create caring environments. The home is a critical setting for provision of informal care. Care is interwoven with social relations within and beyond the home, and it depends on relations of trust and mutual effort. People’s experiences of home strongly affect the intensity and outcomes of informal care. These experiences differ by gender, age, and so on, according to socially and culturally defined roles and relationships. The geographies of informal care have been studied for vulnerable populations, notably immigrants, who rely on place-based social networks and local cultural resources as important sources of informal care. Everyday rituals related to food preparation, prayer, and social interaction are important in immigrants’ efforts to maintain health and well-being in an unfamiliar environment.

In many countries, privatization and devolution policies are shifting the balance between formal and informal care, creating new geographies of informal care. Patients are being released from the hospital earlier and placed in the home and other nonmedical settings. Known as place switching, this process has important implications for both patients and caregivers. For patients, the home is often a therapeutic site that promotes health and healing, so the shift to the home may be beneficial. For caregivers, however, attending to patients’ medical needs at home creates emotional, time, and financial challenges for family members. Frequently, the work of informal caregiving falls more heavily on women than on men, with implications for women’s daily activity patterns and social and emotional well-being. The process of caregiving also has a strong geographical component, depending on the availability of resources, services, and social support within the local community.

**Conclusion**

The uneven geographies of health and health care are continually shaped and reshaped by the interactions between people, places, and institutions. Economic, social, and environmental transformations affect people’s health by affecting their vulnerabilities and exposures and their access to resources, services, social networks, and health care. Although worldwide health has improved in the past several decades, we are also seeing new kinds of health concerns, new vulnerabilities, and widening health inequalities in many places. At the same time, health care landscapes are in flux as cost pressures and political imperatives alter the balance between formal and informal care and as patients, caregivers, and providers adjust to the changing health care environment. How these processes unfold is critically important for the changing geographies of health and health care.

*Sara McLafferty*

See also Accessibility; Cancer, Geography of; Cholera, Geography of; Disability, Geography of; Disease, Geography of; GIS in Health Research and Health Care; HIV/AIDS, Geography of; Malaria, Geography of; Medical Geography; Mortality Rate

**Further Readings**


Heavy Metals as Pollutants

Heavy metal is a poorly defined term that refers to a metallic or metalloid element with a high density and high atomic weight. There is considerable disagreement about whether both or only one of the parameters must be high and about where to set the cutoff values for the parameter(s). Values of 4, 5, and 6 g/cm² (grams per cubic centimeter) have been used to define high density; 23, 40, and 63 have been used as cutoff values for atomic weight. To remedy these inconsistencies, another parameter, atomic number, has occasionally been used to define heavy metal, but this sometimes resulted in the inclusion of obviously light metals in the list of heavy metals. The absence of a consensus about the definition of the term heavy metal has led some to abandon it altogether and use alternatives such as toxic metals or trace metals. However, these terms also lack a universally accepted definition and do not result in a classification that completely overlaps with the general intent for the meaning of heavy metal. Consequently, heavy metal is still a very widely used term. Metallic elements that are generally considered to be heavy metals include antimony, cadmium, chromium, copper, gold, lead, mercury, nickel, silver, thallium, tin, and zinc. Arsenic and tellurium, both metalloids, and even selenium, a nonmetal, are sometimes included among the heavy metals. Depending on the definition used, the list of heavy metals can have between 40 and 80 elements. Many of these heavy metals are toxic to some degree to humans and other life forms, and therefore, sometimes toxicity is included in the definition of heavy metal. Because of their toxicity, their widespread release into the environment through natural and anthropogenic processes, and their persistence under natural conditions, many heavy metals are of great environmental and human health concern. This entry discusses the sources of heavy metals and their environmental distribution. It then describes their adverse health effects as well as national and international regulatory standards.

Sources of Heavy Metals

Heavy metals have a natural origin and can be released into the environment through weathering of minerals and their subsequent spread by geological, atmospheric, and biological processes, including erosion, volcanic eruptions, salt spray, wildfires, and uptake by plants. Heavy metal concentrations resulting from these natural processes are generally low beyond the vicinity of ore deposits. Human activities are a much more important source for most of the heavy metals. Anthropogenic release of heavy metals probably began with the onset of the Bronze Age and the mining and smelting of ores and may have affected the atmosphere at a hemispheric scale by 2,500 years BP (before present). Releases reached the first peak in Roman times, when the use of lead, and also copper and zinc, increased markedly. With the advent of the Industrial Revolution and the associated increase in metallurgical activities and burning of fossil fuels, anthropogenic release of heavy metals increased exponentially. Peak releases of various metals occurred at different times during the 20th century as a result of changes in metal usage and fuel type, but they generally occurred in the 1970s. In that period, atmospheric emissions of lead were about 200 times higher than in prehistoric times. Currently, shifts in release volumes and patterns are taking place as a result of shifting patterns in industrial manufacturing.

Common present-day anthropogenic sources of heavy metals include mining, metallurgy and smelting, industrial and domestic wastewater, electroplating and galvanization (cadmium, chromium, nickel, zinc), combustion of fossil fuels (cadium, lead, nickel), coal-fired power plants and incinerators (arsenic, mercury), and fertilizers (uranium) and pesticides (arsenic, copper). Other human activities such as deforestation, dredging, and construction do not release additional heavy metals to the environment but accelerate their cycling through ecosystems.

Environmental Distribution of Heavy Metals

Because of the numerous sources and environmental persistence, heavy metals occur in virtually all parts of the environment, including air, water, soil, sediments, and plants and animals. In the atmosphere, many types of heavy metal compounds are present, usually in particulate form. Mercury occurs mainly in a gaseous state. Due to
HEAVY METALS AS POLLUTANTS

the dynamic nature of the atmosphere, the heavy metals can be transported over great distances and can reach remote areas such as the Arctic. Particles are removed from the atmosphere by wet or dry deposition. The dry deposition rate is determined by the concentration of the heavy metals in the air, particle size, meteorological conditions, and the roughness and filtering quality of the receiving surface. Wet deposition rates are determined by precipitation amount and the concentration of the heavy metal in meteoric water. Atmospheric deposition is a major contributor to heavy metal pools in soils and surface waters. Water bodies in urban and industrial areas can receive up to 50% of their chromium and up to 90% of their cadmium, lead, nickel, and zinc from atmospheric deposition. Airborne heavy metal compounds are also of concern because they can be inhaled and cause health problems in humans.

In water, heavy metals can occur in a dissolved state, but concentrations are generally relatively low. Arsenic, cadmium, and selenium have the highest proportion of dissolved species. For most other heavy metals, higher concentrations are usually present in colloidal hydroxides, oxides, or sulfides and are adsorbed to suspended clay or organic matter. Heavy metal speciation in water depends strongly on the salinity of the water. When fresh riverine water enters an estuary, for example, organic complexes and particulates may flocculate and promote settling of heavy metals.

In aquatic sediments, heavy metals may be bound by organic compounds and may adsorb to the negative exchange sites at the surface of particles of clay minerals. Concentrations are often higher in sediment than in overlying water. Exchange of heavy metals between the sediment phase and water depends on the chemical
properties of each heavy metal, but desorption from the sediment is favored by low pH, low redox potential, and high salinity. Heavy metals may also flux into the overlying water due to microbial mineralization of organic matter and resuspension of sediments.

In soils, the natural background levels of heavy metals are determined by the composition of the parent material of the soil and the geological and pedological processes that affect it. Anthropogenic heavy metals enter soils mainly via atmospheric deposition, but they can also be added by land application of wastewater sludge and other industrial and dredging spoils and by overapplication of fertilizers and pesticides on farmland. Once in the soil, retention of the heavy metals is greatly affected by the amount and type of organic matter and clay. Heavy metals can also react with anions in the soil and precipitate. In general, soils are efficient in retaining heavy metals under natural conditions, which has led to soils being compared with a filter that cleans the percolating water. Under specific environmental conditions, however (e.g., low redox potential, low pH, very high metal concentrations, the presence of chelating agents), heavy metals can become mobile in the soil environment and leach into groundwater aquifers. Arsenic, mercury, and selenium are subject to volatilization and can transfer from the soil to the atmosphere.

In organisms, heavy metals tend to accumulate faster than they are released, thus leading to bioaccumulation. In water, bioaccumulation is affected by pH, redox potential, availability of complexing agents, salinity, temperature, light, and several biotic factors. In soils, low pH and high clay and organic matter contents raise the availability of heavy metals to plants. Heavy metals, with the exception of mercury, do not biomagnify in the aquatic food chain. The bioavailability of the metals decreases in successive levels of the food chain due to the formation of closed cellular compartments and of insoluble phosphate and sulfur compounds that are not absorbed by the digestive systems of the higher trophic levels.

### Adverse Health Effects of Heavy Metals

In small amounts, some heavy metals such as cobalt, copper, iron, manganese, selenium, and zinc have beneficial effects on human and animal health. However, it has been known since ancient Greek and Roman times that some heavy metals have adverse health effects. It is now well-known that heavy metals such as arsenic, cadmium, chromium, lead, and mercury are toxic to many life forms, even at low levels. They are taken up by humans through dermal contact, inhalation, and ingestion of water, food, and dust. Children are more prone to adverse health effects from exposure to heavy metals than adults because of the greater risk of accidental ingestion and unhygienic habits. A wide range of health problems can result from exposure to heavy metals, including respiratory problems, liver and kidney damage, nerve damage, cancer, and birth defects. Diseases of the brain are the leading cause of human mortality from acute and chronic heavy metal exposure. Some heavy metals are radioactive (cobalt, uranium). In the United States, chronic exposure to lead, commonly present in paint in older housing, is the most significant cause of heavy metal poisoning. Children are especially vulnerable because they absorb more of the ingested lead than adults (50% vs. 10%). Exposure to lead in the uterus or during the early years of life may lead to birth defects, developmental delays, and decreased intelligence. However, morbidity and mortality due to heavy metal exposure are low compared with other illnesses and conditions, except for small-scale exposures to elevated levels.

In plants, both deficiencies and excesses of heavy metals can have negative impacts. Essential elements such as cobalt, copper, manganese, and zinc are required for healthy plant growth. Arsenic, cadmium, chromium, lead, and mercury are toxic to plants to various degrees. The level of toxicity of heavy metals depends on the bioavailable proportion rather than the total concentration. Bioavailability depends on abiotic factors such as pH, the type and amount of clay and organic matter, microbial activity, and moisture content but is also greatly influenced by the plant species and growth stage.

### Regulatory Limits

Many nations and international organizations have established environmental standards for heavy metals. The regulations provide acceptable
concentration limits for heavy metals in various media and are intended to safeguard ecosystem and human health. The establishment of the standards has been the subject of considerable debate because of the multiple confounding factors—such as metal speciation, bioavailability, interspecies variability, and interaction with other toxins—that affect the toxic effects of a heavy metal. As a result, a number of standards have been developed for different purposes, with different methods, and for various media. For plant health, few standards have been established, in part because of the large variability in toxicological effects a given metal concentration has on various plant species.

Lead is the only heavy metal classified as a criteria (major) air pollutant in the United States, with a maximum quarterly average standard of 1.5 μg/m³ (micrograms per cubic meter) of air. Standards for water quality in the United States depend on the specific designated use(s) of a water body, such as recreation, support of aquatic and/or wildlife, propagation and harvest of aquatic life, and drinking water source. Some of the current maximum contaminant levels for drinking water sources are 0.01 mg/L (milligrams per liter) for arsenic, 0.005 mg/L for cadmium, 0.1 mg/L for chromium, 1.3 mg/L for copper, 0.015 mg/L for lead, 0.002 mg/L for mercury, 0.1 mg/L for nickel, and 0.05 mg/L for selenium. Standards for aquatic sediments have been established to protect benthic fauna but also because of the influence of sediment pollution on water quality. A wide range of standards exists for sediment quality, most of which are based on a certain probability of some type of adverse biological effect. Safe limits for heavy metal intake by humans are based on the daily or weekly provisional tolerable intake level, which is the upper limit for the amount of a chemical that can be ingested each day or week without appreciable risk to a person’s long-term health. The provisional tolerable intake level is calculated based on toxicological tests, epidemiological and accidental exposure information, and a safety factor that takes into account differences between humans and test animals, differences among people, and the nature of the potential health effect. FAO/WHO (Food and Agricultural Organization/World Health Organization) daily provisional tolerable intake values for some heavy metals are 2.1 μg/kg for arsenic, 1 μg/kg for cadmium, 500 μg/kg for copper, 3.6 μg/kg for lead, 0.7 μg/kg for mercury, and 1,000 μg/kg for zinc.

Johan Liebens

See also Atmospheric Pollution; Biogeochemical Cycles; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Impacts of Roads; Open-Pit Mining; Soil Degradation; Water Pollution

Further Readings


Hegemony refers to the ability of a dominant group to influence and shape others’ attitudes, perceptions, and actions. In contradistinction to related phenomena such as imperialism or empire, hegemony does not rely on force or violence and instead requires considerable consent from the
subordinated group. This entry discusses the evolution of the concept of hegemony and its application in geography.

Much of the theorization and application of hegemony is based in Marxist thought. The Italian theorist Antonio Gramsci developed the notion of cultural hegemony around 1930 to explain why the working class had internalized or adopted the capitalist values of the bourgeoisie rather than carrying out the revolution predicted by Marxist theory. Gramsci opposed Marx’s economic determinism, positing that the values and norms adopted by the masses were disseminated primarily by civil society groups such as churches, schools, and intellectuals. The state, or political society, applied coercion through its juridical institutions only when people did not consent to the imposed order willingly.

The Frankfurt Institute for Social Research, or the “Frankfurt School,” dedicated to neo-Marxist critique of ideology, contributed greatly to the notions of hegemony throughout the mid 20th century. Herbert Marcuse, a key Frankfurt thinker, wrote that in advanced industrial (post-1945) societies, social critique is stemmed by technology and consumerism, which occupy passive subjects with created false needs. Thus, marginalized voices are the only source of true dissent. More recently, Ernesto Laclau and Chantal Mouffe departed from previous views of hegemony (such as those of many Frankfurt thinkers) as a secondary phenomenon of production relations. Instead, they characterized all contemporary social relations as hegemonic struggles whose outcomes were discourse and the construction of political identities, as well as new resistances. Thus, in contrast to the totalizing consumerism of which Marcuse spoke, Laclau and Mouffe actually saw the post-1945 climate as more conducive to counterhegemonic movements.

Hegemony has received considerable attention in geography, particularly because it informs the social construction of space and place and the ways in which power and ideology are implicated therein. Edward Soja, building on Henri Lefebvre’s notions of the production of space, introduced the term *sociospatial dialectic* to explain the production of space from a Marxist spatial-analytical perspective. Soja (1980) noted that the structure of organized space represents “a dialectically defined component” of the relations of production, which are “simultaneously social and spatial” and arise from “purposeful social practice” (pp. 208–210). In Soja’s account, the social production of space was an integral component of class struggle that reinforced the hegemony of contemporary capitalism, though in a dialectical, rather than mechanistic, way.

A number of cultural geographers have gone beyond this materialist context and examined the production of hegemonic identities and relations beyond class. Tim Cresswell demonstrated how place is constructed around multiple ideological practices and beliefs through hegemonic and counterhegemonic struggles. The construction of place is recursive: Place reproduces the beliefs that have produced it, and these beliefs eventually come to appear self-evident and a matter of commonsense. This issue has been examined in the construction of commemorative places, which aim to “etch” a particular collective memory into the cultural landscape, thereby asserting certain identities as dominant while marginalizing others. For example, African Americans and civil rights activists have protested the creation of memorials to Confederate general and Ku Klux Klan leader Nathan Bedford Forrest. Derek Alderman and Owen Dwyer viewed a memorial to Forrest in an African American neighborhood in Selma, Alabama, as one such example of the operation of collective memory.

In the subfields of political geography and geopolitics, the workings of hegemony at the global scale have been theorized and empirically demonstrated. Some of these understandings are taken from Immanuel Wallerstein, who posited that hegemony occurs in the capitalist world system when a particular state achieves economic, political, and ideological dominance, though it is rooted in that state’s supreme efficiency in economic activities. Peter Taylor examined the rise of the three hegemons in the capitalist world economy (the Netherlands, Britain, and the United States). He noted that their economic supremacy was buttressed by sets of political rules and norms set forth by each and advanced largely by their civil societies, which he termed *prime modernity*. Hence, the hegemon serves as a source of moral and intellectual leadership as well as an example of economic progress for the rest of the world to emulate.
The phenomenon of U.S. hegemony has been viewed by some political geographers as unique from previous examples of hegemony. For example, John Agnew viewed post–World War II globalization and its fragmentation of state territories as a hegemonic project closely linked with U.S. political and economic interests, indicating a break with the exercise of power by previous hegemons. Similarly, Neil Smith saw the U.S. imposition of relational power, rather than direct, imperial control of territory, as the basis for a U.S.-dominated world order in which legitimacy was predicated on membership in the community of “free” nation-states. There is little consensus over the current state of U.S. hegemony. Some scholars see the United States as a hegemon in decline, while others, such as John Agnew and Stuart Corbridge, broach the idea of a stateless hegemony in which the world order is governed by a hegemonic ideology of transnational liberalism and expansion of global capitalist markets.

While scholars such as Marcuse viewed hegemony as totalizing, Gramsci emphasized that maintaining hegemony does not require constant acquiescence from subordinates; rather, the dominant group carefully defines the acceptable range of resistance to its order. Indeed, Gramsci even acknowledged fluidity in the elite group itself. Thus, hegemony requires continuous effort on the part of those whose interests it serves. This is emphasized by John Agnew, who points out that as the United States has met with resistance from certain parts of the world, it has had to resort to increased unilateral actions and use of force. Importantly, these policies are often questioned even within U.S. society. Laclau and Mouffe noted that while capitalist relations pervade virtually every domain of life, new struggles have fomented in resistance to new forms of subordination, such as the ecological movement, which opposes wasteful and destructive capitalist practices. Paradoxically, the possibilities for success are somewhat limited by dissenters’ reliance on aspects of the capitalist system to support their movements.

Richelle M. Bernazzoli

See also Colonialism; Cultural Landscape; Geopolitics; Imperialism; Inequality and Geography; Marxism, Geography and; Political Geography; Race and Racism; World-Systems Theory

Further Readings


Herbicides are a subclass of pesticides that are designed to kill unwanted plants or inhibit their growth. Herbicides contain a wide variety of chemicals, including both inorganic and organic compounds, with different abilities to interrupt specific physiological processes of plants for their survival, growth, and development. The use of herbicides provides a cost-effective method to control the growth of unwanted plants in order
to decrease labor costs and increase crop production. Herbicides are extensively applied in agriculture, forestry, and urban areas for unwanted plant management. In addition, herbicides are often used to control nuisance aquatic plant growths or algae blooms in water bodies.

Initially, most chemical herbicides were inorganic compounds that were usually very toxic to both desirable crops and unwanted plants as well as to mammals. The first synthetic organic herbicide was developed in France in 1932 for use in cereals. The rapid development of synthetic organic herbicides was stimulated by the need for increasing food production and by the Allies’ search for potential chemical warfare agents during World War II. Since then, the development and use of herbicides have increased steadily. Indeed, herbicides are the most commonly used pesticides in the world today. Most of the heavy herbicide use takes place in North America, Europe, Japan, and Australia.

There are various herbicide classification schemes based on different herbicidal properties. According to their activity, herbicides can be simply classified as (1) selective herbicides, which are used to kill unwanted plants without harming others, or (2) nonselective herbicides, which kill all plants. According to their movement within the plant, herbicides can also be classified as (1) contact herbicides, which destroy only the plant tissue in contact with the herbicide, or (2) systemic herbicides, which are absorbed either by the roots or the foliar parts of a plant and are then carried throughout the plant to injure it. According to application timing, herbicides are classified as (1) preplanting herbicides, which are applied before a crop is planted; (2) preemergent herbicides, which are applied before the emergence of unwanted plants; or (3) postemergent herbicides, which are applied after crops or unwanted plants have emerged. Herbicides with similar chemical structure often disrupt the same biochemical process in plants. Therefore, herbicides are commonly grouped by their chemical structure and mechanism of action. Understanding a herbicide’s mechanism of action is helpful in choosing the appropriate type of herbicide for effective plant management.

Herbicide use plays an important role in modern agriculture by increasing crop production at low labor cost and decreasing soil erosion through reduced tillage. Although most herbicides are specific plant poisons and have a very low toxicity in animals, some herbicides can be highly toxic to humans and other animals. Herbicides can potentially affect ecosystems by having direct toxicity to nontarget organisms, altering vegetation compositions and habitat structure, or reducing food sources. In addition, some water-soluble herbicides may contaminate surface and groundwater resources, with adverse effects on aquatic fauna. Improper herbicide use can cause negative impacts on the environment and pose a health threat to herbicide applicators and others exposed to herbicides via drinking water or food. Despite their contribution to food production, herbicides must be used appropriately to reduce their risks.

Mei-Hui Li

See also: Agrochemical Pollution; Environmental Impacts of Agriculture; Pesticides; Pest Management

Further Readings


**Herodotus**

*(ca. 484–ca. 425 BC)*

Herodotus (born in Halicarnassus, ca. 484 BC; died in Thurii, ca. 425 BC) was a Greek historian and geographer. His value in the history of geography is related essentially to his focus on ethnicity. His hometown had frequent relations with the so-called barbarian world, and that, together with his extensive travels, especially through the lands of the Black Sea and the Mediterranean Sea, contributed to developing his great curiosity about different countries and allowed him to come in contact with various populations, their traditions, and their customs.
His work *The Histories* provides considerable interesting geographic and cultural information, and for this reason, Herodotus has been described as the father of ethnography as well as the father of history. Among the topics dealt with in his writing are the cultures of Persia, Assyria, India, and Arabia; the customs of various and sometimes legendary populations such as the Hyperboreans, the Androphagi, the Budini, and the Melanchlaeni; and the geography of Scythia and Egypt. The label that he gave to the latter country—“the gift of the Nile”—is still famous and was meant to underline the importance the river’s course had in the development of Egyptian civilization.

In some cases, as in his account of the Nile, whose sources he believed to be in the Atlas mountains, Herodotus’s geographical knowledge was erroneous; moreover, his words sound imaginative and unreliable on many occasions. However, through collected stories and interviews, he succeeded in describing in a very suggestive way those territories beyond which the world was, at the time, imagined to be uninhabited. Thus, for instance, India became the symbol of distance and mystery both from the physical point of view and from the cultural one. He only reached its boundaries, but he wanted to report about the supposed immense quantities of gold that could be found there and its incredible animals, much bigger than those of any other place. He described ceremonies and traditions that he did not know, supported by the idea that in such far-off countries, everything could be possible.

Herodotus’s view of the world was based on a sort of ethnocentrism that expressed itself through the processes of analogy and opposition, keeping Greece as a reference. He postulated that his homeland was at the center of the inhabited area of the world and that the areas distant from it were the most different from Greece, from both the environmental and the cultural points of view. He also considered Greece to have the most favorable location and climate. According to him, at the borders of the known inhabited world, people had to face the hazards of cold weather or unbearable heat, but on the other hand, they could sometimes enjoy extraordinary natural riches.

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**Further Readings**


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**HETTNER, ALFRED (1859–1941)**

Alfred Hettner was a prominent and highly influential German geographer who powerfully shaped the nature of the discipline in the late 19th and early 20th centuries. Greatly influenced by Immanuel Kant, Alexander von Humboldt, and Carl Ritter, Hettner argued that geography consisted of the art of holistic regional description and synthesis, inductively seeking relations among phenomena that other disciplines ignored, particularly those between humans and the environment.

Son of a museum director in Dresden, Hettner grew up in comfortable circumstances. He started his higher education at the University of Halle in 1877. He moved to Bonn a year later and to Strasbourg a year after that. Much of his training was focused on physical geography. In 1897, he became a professor at Tübingen and later at Heidelberg, where he spent the remainder of his career. He placed great emphasis on the importance of fieldwork and undertook extensive journeys throughout Europe, Russia, and South America, emphasizing climatology and geomorphology and publishing books on all these regions. Health problems gradually forced him to abandon fieldwork and confined him to a wheelchair, although he achieved the status of the leading German theoretician in the discipline. His work became increasingly sophisticated theoretically, leading him to move away from Kant and to advocate more relational views of space.
At times, he engaged in sharp polemical debates with his peers. In 1895, Hettner founded and edited the widely read journal *Geographisches Zeitschrift* (Geographic Periodical).

Rather than embracing all the Earth sciences, as previous generations of German geographers maintained, geography for Hettner was the study of why differences among regions appeared and persisted: The core of the discipline was comparative regional analysis. However, he did not hold to a naive empiricism in which geographic regions and facts were simply given but, like Kant, believed them to be constructed through the mental imposition of conceptual order on Earth’s surface. The relations between the abstract and the concrete, the general and the specific, representations and reality, always loomed large, in this view. Thus, for him, geography was defined by its methodology, not its content, and he viewed the growing schism between human and physical geography with alarm. His attempt to focus the discipline around regional synthesis should be seen in light of European colonialism more generally and German nation building and expansionism in particular.

In contrast to the increasingly reactionary geopolitics of Friedrich Ratzel and Karl Haushofer, Hettner represented the progressive face of German geography. In this respect, he shared much with his French counterpart Paul Vidal de la Blache. Both men argued against the racism and xenophobia of geopolitics and environmental determinism, emphasizing instead the constitutive role of culture. By the 1930s, the rise of the Nazis put him in an increasingly precarious professional position.

Hettner was also long active in promoting geography in the schools at all levels and wrote several textbooks. His main disciple was Richard Hartshorne, who carried Hettner’s Kantian worldview to the United States (but not unchanged in the process) and played a dominant role in the American version of chorology.

Barney Warf

See also: Chorology; Empiricism; Hartshorne, Richard; Human Geography, History of; Humboldt, Alexander von; Kant, Immanuel; Regions and Regionalism; Ritter, Carl; Vidal de la Blache, Paul

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**Heuristic Methods in Spatial Analysis**

Many problems in spatial analysis involve the search for optimal solutions. For example, it is important to find locations for public health facilities such that the residents in an area can be best served. There are exact methods that can be used to solve these problems. An exact method exhaustively evaluates each possible solution and identifies the best one. A drawback of this type of approach is its complexity. For a large-sized problem, as measured by the number of inputs, the time used by an exact method may exceed the time frame required to solve the problem. The predicament of solving a problem exactly suggests the use of heuristic methods. Different from exact methods, heuristics generally do not guarantee that the optimal solution will be found.

To understand how a heuristic method works, it is helpful to imagine a graph formed by all the solutions to a problem, where each vertex represents a specific solution and a link exists between two vertices if knowing one will lead to the other (see example that follows). Finding the optimal solution in the network requires starting from any vertex and finding the path to the vertex representing the optimal solution. As the graph can be
of a huge size because of the number of vertices (possible solutions) and their connections, it is impractical to exhaustively traverse each path between vertices. A heuristic method often starts from a randomly chosen vertex and tries to go through a particular path by guessing that there is no need to go through other paths. The chosen path, however, does not necessarily lead to the optimal solution, though the literature generally suggests that near-optimal solutions can be found.

Many heuristic methods are developed using a “greedy” mechanism (one that solves problems by finding locally optimum solutions in the search for a global optimum) to improve the initial solution that is typically determined on a random basis. Though different forms of greedy methods exist, they generally follow the same design logic: If a better solution can be found in the neighborhood of the current solution, then the current solution should be replaced by the new one. The process continues until no such replacement can be made. This idea can be illustrated using a solution approach to the $p$-median problem, where $p$ nodes must be selected in a network of $n$ nodes such that the total distance from each node to its nearest selected node is minimal. An initial solution to the problem can be $p$ random, unique integers ranging between 1 and $n$. Substituting a selected node with each of the unselected ones results in a neighborhood of the solution. The current solution can be improved if at least one solution in the neighborhood has a smaller total distance. The replacement continues until no solution is better in all the neighborhoods of the $p$ selected nodes.

Greedy heuristic methods are typically designed for specific problems, which makes it difficult for one method to be used to solve other problems. Also, a greedy method is often myopic, meaning that it can be trapped in a local optimal solution. Metaheuristics have been developed with the hope of addressing these issues.

The diverse family of metaheuristics includes methods such as evolutionary algorithms, simulated annealing, ant colony systems, and tabu search. Different from greedy heuristics, these methods may accept solutions that are worse than the current ones. This feature allows the search algorithm to make “mistakes,” especially at the early stage of the iterations. A second characteristic of metaheuristic methods is that they are often inspired by a natural process. Evolutionary algorithms, for example, are computer programs that simulate evolution and natural selection in biological systems. A third feature of metaheuristic methods is that they can be used to solve a wide range of search problems.

Evolutionary algorithms have been widely used in spatial analysis. An evolutionary algorithm maintains a set of solutions called a population that is often randomly initialized. Each solution in the current population has a chance to be used to create the next generation, though solutions considered to be good have high chances. New solutions are generated using a recombination operation that combines the elements of two solutions selected from the current population. A new solution can be further altered by a mutation operation that introduces unexplored elements into the population. This process continues until a predefined condition, say, the maximum number of iterations, is reached. Using a $p$-median problem (with $p = 5$ and $n = 10$) as an example, a solution can be represented using a string of five integers, such as $(1, 2, 6, 7, 8)$ and $(2, 3, 8, 9, 10)$. Different approaches can be used to recombine these two hypothetical solutions. For example, the two solutions can be rearranged so that the common elements are listed first and the other elements are listed in an ascending order, namely, $(2, 8, 1, 6, 7)$ and $(2, 8, 3, 9, 10)$. Two new solutions can be generated using a random break point in the unshared elements and exchanging the elements between the two solutions. Using a break point between the third and fourth elements yields $(2, 8, 1, 9, 10)$ and $(2, 8, 3, 6, 7)$. A mutation operation can be used to change an element in the second new solution, so that it becomes, for example, $(2, 8, 5, 6, 7)$.

Heuristic methods have their limitations. They may not be desirable if the goal is to find the optimal solution. Practically, the performance of a heuristic method may be sensitive to its parameters, which often need to be fine-tuned. Searching for parameters that lead to satisfactory performance may itself be a difficult problem.

Ningchuan Xiao

See also Location-Allocation Modeling; Spatial Analysis; Spatial Decision Support Systems; Spatial Optimization Methods
High-performance computing (HPC) is an approach for handling computationally demanding tasks that are beyond the computing capabilities of a single processor. The complexity of geographic problems creates an urgent need for high-performance computing. High-performance geocomputation is a new frontier that combines expertise from geocomputation (the art and science of solving complex spatial problems with computers) and HPC.

A widely acknowledged measure for high performance is floating point operations per second (FLOPS). High-performance computers have the computing capabilities of teraFLOPS ($1 \times 10^{12}$ FLOPS) or even petaFLOPS ($1 \times 10^{15}$ FLOPS). Currently, parallel computing is the mainstream of HPC. Parallel processing aims to improve computational performance by executing the same task with multiple processors simultaneously. A more recent parallel-computing trend is cluster computing, which takes advantage of commercial, off-the-shelf components. Cluster computing is the most popular type of parallel computing for users who cannot afford the high cost of building parallel-computing systems. A famous example is the Beowulf-style cluster, which builds low-cost parallel-processing systems with PC and Ethernet networks. The common software programming models used in clusters are message passing interface and parallel virtual machine. Beyond cluster computing, a much more ambitious idea—one that is leading the development of grid computing—is to use spare computing resources all over the world by means of a decentralized management strategy.

Early research on high-performance geocomputation involved migrating existing serial algorithms to a parallel-processing framework and experimenting with parallel spatial data analysis including simple map analysis operations, terrain analysis, network analysis, and spatial autocorrelation. Since then, grid technologies have been rapidly developing to better integrate large-scale computational resources and services. The development of grid systems is quickly migrating toward SOA (service-oriented architecture), which promises a suitable platform for implementing geographic information system (GIS) services and improving their performance and integration. However, most grid tools today provide only general-purpose protocols that need to be modified to fit the special needs of geospatial applications.

A number of current GIS grid projects share a similar technical foundation while addressing different problems. These projects include the GEON (the Geosciences Network: Building Cyberinfrastructure for the Geosciences), ESG (Earth System Grid), and GISolve. The Globus Toolkit is currently the de facto grid middleware system that nearly every project uses as the supporting tool for grid-based applications to interact with grid resources.

The advantages of combining HPC technologies with geocomputation include the speed-up of computational time, thus enabling the near-real-time simulation and analysis of large data sets. Despite the advantages, the use of HPC in geocomputation and geographic analysis is still rare. The lack of easy-to-follow examples, the requirement of considerable computer science skills to access and effectively use HPC resources, and the seemingly high cost of transition from traditional- to parallel-programming paradigms discourage geographers from adopting HPC. To promote the use of high-performance geocomputation, more successful demonstrations are needed to provide opportunities for learning. Additionally, the cost of building and accessing HPC resources has to be lowered. The installation and management of HPC tools

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Further Readings

need to be simplified to remove geographers’ reservations about adopting high-performance geocomputation.

*Tong Zhang and Piotr Jankowski*

*See also* Geocomputation; GIScience

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**Further Readings**


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**High Technology**

*High technology* refers to the applied use of sophisticated knowledge and is commonly associated with scientific and engineering innovations. High-technology industries are characterized by the broad application of innovations to a multiplicity of intermediate and end products as well as both process and product innovations.

This broad application has led to the common characterization of high-technology industries as “enabling” industries. They contribute to innovations in traditional industries and form the technical basis for emerging industries. High-technology firms provide devices and processes that are applied to a range of industrial contexts, including new hi-tech consumer end products (e.g., smart phones, digital cameras) and intermediate products for traditional industries (e.g., geographic information systems [GIS] in automobiles). High-technology industries include biotechnology, nanotechnology, information and communication technologies, and a range of material sciences (e.g., advanced polymers).

High technology is often associated with important intermediate products and process innovations, including software and microelectronics. Much of the focus of high-technology industries is on the research and development phase of production, although there are high-technology end producers. Consequently, the central inputs and locational factors for high technology are human and social capital and research and development capacity. Evidence indicates that high-technology firms tend to locate close to pools of skilled labor and close to each other.

A distinctive characteristic of high-technology industries is their extensive potential markets with (relatively) small production footprints. High-technology industries are often measured by significant patent rates and venture capital investment. These metrics are also applied to high-technology industrial districts and innovative regions. However, the measurements are imprecise. For example, the auto industry and agricultural industries have extensive patents and large research and development divisions but are generally considered to be traditional industries. Indeed, a discrete definition of “high-technology” firms, occupations, industries, or regions is complicated by their enabling role across multiple supply chains. Accordingly, high-technology occupations and industries are loosely understood as high skill, high wage, and high value-added.

The geographic distribution of high technology is a significant area of research, theory, and policy practice. Geographers have produced numerous studies of high-technology industrial districts such as Silicon Valley and Boston, as well as studies of the location patterns of industries such as microelectronics, biotechnology, and photonics. Simultaneously, theories about the development of high-technology regions have emerged that include learning regions, regional innovation systems, the “creative class,” the spatial implications of tacit and codified knowledge, and the factors that create an “innovative milieu.”

These theories and the body of empirical work that has grown around them have informed an emerging set of public policies aimed at technology-led economic development strategies. These policies include public investment in
targeted science and technology policies, expansion of applied university research, technology transfer programs between universities and industries, and investment in science parks, research centers, and high-technology incubators. The coordination of these policy strategies has become increasingly conscious of the spatial distribution of high-technology activities and is increasingly organized into and around regional innovation systems in both industrialized and industrializing countries.

Jennifer Clark

See also Agglomeration Economies; Clusters; Electronics Industry, Geography of; Flexible Production; Industrial Districts; Innovation, Geography of; Technological Change, Geography of

Further Readings


Hipparchus (born in Nicaea) was a Greek geographer and cartographer who was also considered to be one of the greatest astronomers of ancient times. Even though almost all his writings have been lost, his theories have been handed down by Ptolemy and Pliny the Elder.

Hipparchus thought that astronomical observations and methods were fundamental for geographic studies. He was also critical of his predecessor Eratosthenes and argued that the geographer of Cyrene developed his theories without the support of mathematical calculations. His attention also focused on the use of instruments such as the diopter (which measures the angles of light), which enabled him to estimate the size of the sun and the moon and their distance from Earth. Through the use of a gnomon (part of the sundial that casts the sun’s shadow), Hipparchus could also determine the latitude of a place, and he estimated its longitude by observing the beginning and the ending of solar eclipses from different places. He calculated the length of the equator to be 39,960 kilometers. Hipparchus was said to have accurately estimated the inclination of the plane of the ecliptic (the intersection of the celestial sphere with the plane of the mean orbit of Earth), and he discovered the precession of the equinoxes (the fact that they move westward along the ecliptic). Finally, he is remembered for having almost exactly calculated the duration of the solar year.

In the field of cartography, Hipparchus was interested in finding a solution to the representation of a spherical surface on a plane. He dedicated himself to the study of the stereographic projection, a particular way of mapping that was probably already known to the Egyptians and that allows the depiction of the curved surface of Earth on a flat map. In cartography, it is used to map the area of the poles, with the result that meridians look like rays originating from a point and parallels look like circles centered at the origin. This type of projection has three essential properties: It is smooth, and conformal, but it does not preserve areas. The fact that it respects angles was extremely useful for navigators in ancient times.

On the basis of sailors’ descriptions of the tides along the Gibraltarian, Spanish, and French Atlantic coasts and of those occurring along the Eastern Asian coastline, and taking into account the observations of the Babylonian astronomer Seleucus of Seleucia, Hipparchus deduced the existence of a vast continent that separated the Indian Ocean from the Atlantic.

Susanna Servello

See also Aristotle; Cartography, History of; Eratosthenes; Herodotus; Human Geography, History of; Knowledge Spillovers

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**HISTORICAL GEOGRAPHY**

Historical geography is the subfield of the discipline that examines geographies of the past, including their relations with those of the present. In his treatise on historical geography, Andrew Hill Clark argues that the past is at least implied, if not explicit, in all geographic analyses. Clark claims that the concepts and methods of historical geography are applicable to all branches of geography, and therefore, historical geography should not be thought of as a distinct field of geography but more as a methodology, as a way of seeing geographically by focusing on space and time. This entry discusses the development of historical geography from the 1890s to the present, including the emergence of a new critical historical geography, beginning in the 1970s. It then examines the practice of historical geography and its relevance as a subfield today.

Like the field as a whole, the practice and role of historical geography in America were transformed by the four major periods of modern geographic thought. The environmental determinism of the early 20th century used historical geography to
create bigoted, unscientific generalizations about how climate influences society. By the 1920s, historical geography held a central position in American geography, as geography’s regional approach repudiated environmental determinism. Historical geography in this period focused on regional narratives that largely examined various aspects of material culture and settlement patterns. The 1950s and 1960s witnessed the quantitative revolution, and historical geography was pushed to the periphery. Finally, influenced by the critical geographies of the 1970s, historical geographies focused on social theory, reflecting the cultural turn in geography, and asked critical questions about culture and identity, economics, politics, scale, and the environment.

Despite these transformations, two things have remained constant throughout each period: (1) the historical geography methodology and its focus on the historical record, primary data sources, and field observations and (2) relevance. As other subfields have increasingly recognized the importance of a historical perspective in answering geographic questions, the need for historical geography as a distinct subfield has been greatly reduced.

### Early Historical Geography

From the 1890s to the 1920s, the first major period of modern geographic thought emphasized the role of the physical environment in determining human behavior and shaping settlement patterns. Geographers such as Ellen Churchill Semple and Ellsworth Huntington, adhering to the theory of environmental determinism, used their interpretations of the historical record to show how environmental factors such as climate determined social actions. In doing so, they constructed a social Darwinist narrative that theorized that Northern Europeans possessed a superior intellect and ability due to the temperate climate of the region, while people of color, living in the tropics, were lazy due to the intense heat of the equatorial region. Historical geography, like the field of geography as a whole, began to move away from the theories of environmental determinism in the 1920s, as the regional approach took hold.

Regional geography focused on descriptive, regional-scale narratives concerning the history of places and regions. These narratives focused on the long-term transformations of a region. Understanding these regional transformations required an understanding of history. Andrew Hill Clark believed that a well-trained historical geographer was simply a well-trained geographer, and a well-trained geographer was a regional specialist who examined changes in the landscape. Carl Sauer and the Berkeley School geographers relied on the historical record to analyze the cultural processes responsible for shaping landscapes. Derwent Whittlesey’s theory of sequent occupance influenced American historical geography by examining the historical record and the built environment for changes in the type, form, and density of settlement patterns in an area. To Whittlesey, true historical geography was chronological in arrangement but spatial in treatment. Fundamentally idiographic, regional and historical geography, focusing on areal differentiation and the unique character of regions, was perceived as descriptive, lacking theory, and unscientific. Critics of regional geography emphasized a systematic, nomothetic approach to geography as a spatial science.

The 1950s were a turning point for geography as it transformed into a spatial science. Inspired by the quantitative revolution, geographers took a more abstract and theoretical approach to space that used modeling and statistics to make geography more scientific. While historical geography had been central to American geography, the focus on positivism began to push the historical perspective to the periphery of the field. In 1953, the Hartshorne-Schaefer debate highlighted the difficulty geographers had in determining the future and of geography and its methodology. Detractors of regional geography, and therefore historical geography, claimed that this type of geography was unscientific and of no practical value. The status of historical geography in American geography declined, and it occupied an increasingly peripheralized position, but by the 1970s, the historical perspective experienced a renaissance with the rise of critical geography.

### The New Critical Historical Geography

By the 1970s, a more critical geography was burgeoning. Critical historical geography was
more than the collection of historical facts and simple description exemplified by the older regional approach. Instead, critical historical geography examined the pressing issues of spatial scale, the social production of landscapes, the social construction of nature, and social identity, including race, class, gender, and sexual identity. Historical geography began asking critical questions about culture, economics, politics, and past and present spatial practices. This critical historical geography accommodated a variety of methodological and scalar approaches and was influenced by three strains of critical geographic thought—humanism, historical materialism, and postmodernism.

Developed as a reaction to the systematic scientific approaches of the quantitative revolution, humanistic geographers believed that human experiences could not be reduced to positivist abstractions. Humanistic geography rejected the idea of geography as a spatial science. Instead, it focused on a more subjective geography that examined people’s experiences in place. By examining the everyday experiences of place, some humanistic geographers wrote historical geographies of ordinary landscapes, since the landscape is an accumulation of past cultural meanings. Other humanistic geographers attempted to bring the use of historiography back. An example is Donald Meinig’s ambitious *Shaping of America* series. In this four-volume sequence, Meinig explores 500 years of historical-geographical transformations that helped shape America by examining the spatial processes of urban growth and expansion, the growth of transportation networks, migration and immigration, globalization, and technological innovations.

Continuing to provide critical historical perspectives, historical geographers turned to Marxist geography, which employs the theories and philosophies of Marxism to examine sociospatial relations under capitalism. Under Marxist geography, historical geography used historical materialism to explain the development of the spatial patterns and processes in society. Unlike the older historical geographies, which described the changes in settlement patterns and land use, historical materialist geography examined the sociospatial relations of the production of space, including the roles of class, power, conflict, and the state. This approach to historical geography examined the social struggles and exploitation that underlie the sociospatial organization of the landscape. In *The Lie of the Land*, Don Mitchell examines the labor relations behind the making of the California agricultural landscape. Unlike the Berkeley School geographers, who described the rural landscapes of rural California, Mitchell used a Marxist approach to show that behind the pastoral images of California lie the social struggles of an exploited invisible army of labor working to produce those idyllic qualities represented in images of the Californian landscape. Inspired by social theory, historical materialist geographies clearly have a moral and political agenda to expose the exploitation and uneven development under capitalism. As part of his historical materialist reworking of geography, David Harvey proposed a historical geography that employs a dual methodological approach that maintains scientific rigor while at the same time being committed to analyze and understand the powerful and conflicting processes of social reproduction. Social theory would continue to influence the development of historical geography as postmodernism and the cultural turn shifted the focus to questions of representation, identity, power relations, and meaning.

By the 1980s, critical historical geography began presenting an eclectic mix of geographies fueled in large part by the cultural turn and postmodernism. Inspired by critical literary theory, this “new” cultural geography relied on textual analysis of the landscape to read visible signs and symbols in an attempt to understand the cultural meanings, ideologies, and values inherent in the landscape. This new phase of historical geography rejected the universal truths of modernity. Instead, it recognized the multiple viewpoints, discourses, and voices that are associated with specific places, times, and contexts. Shaped by the new cultural geography and its focus on representation, this phase of historical geography began to recognize that the gaze of geographers is filtered through the lenses of culture, language, race, gender, class, and sexual identity. Historical geography began to address the historical aspects of power relations associated with forms of social identity by examining the production of space as the result of social struggles. Of particular importance to the growth
of this new phase of historical geography was the connection between feminist geography and the historical record.

Feminist geography examines sociospatial relations and the geographies of difference with reference to uneven gender relations, the social construction of gender, space and place, geographies of sexual identity, and children's geographies. In combining the fields of feminist geography with historical geography, feminist geographers challenge the traditional, antiquarian historical methodology as essentially patriarchal since it erases the role of women and other underrepresented groups from the narrative. The rigorous archival work and field observation of historical geography created the distance necessary to retain the appearance of objectivity. But as feminist geographers point out, no study can be totally objective due to the biases that the researcher brings to each study. In accepting the traditional methods of historical geography as well as the identities and roles of the past, historical geographers reify the notion of difference. In addressing the historical geography of difference, Mona Domosh calls for a reformulation of historical geography methods that are sensitive to the gendered, racial, classed, and sexual constructions of space, place and landscape. This new phase employed a critical historical-geographical way of seeing the past to analyze the cultural contexts of place.

### The Practice of Historical Geography

In his assessment of the state of historical geography, Donald Meinig argued that historical geography was essential to the health of the field of geography. He also maintained that as a subfield, historical geography was not simply a body of facts or theories just waiting to be applied. Instead, he claimed, historical geography is a perspective, a way of seeing and thinking. Central to this perspective is the reliance on the historical record and primary data sources, including textual data in archives and visual data gained through field observations. Investigating the archives, historical geographers face a flood of primary documents. While historical geographers may uncover statistical or cartographic documents, the archives are full of written documents including, but not limited to, letters, diaries, journals, newspapers, reports, city records, company records, planning documents, and meeting minutes. Cole Harris argued that the archival scholarship that is essential to historical geography is an evolving interaction between the researcher and past voices embedded in the documents. The practice of historical geography relies on the triangulation of data and methodologies (e.g., visual data from on-the-ground field observation, data from a variety of archival sources, and ethnographic data from oral histories).

The use of narrative is essential to historical geography. Scholars in a variety of disciplines rely on the use of narrative, but the placing of theory into the narrative is what sets historical geography apart from other disciplines. In comparing historical geography and history, Don Mitchell argues that historical geography, unlike history, uses the historical record to develop a theoretical argument through which to tell a story. Historical geography needs to realize the importance of its theoretical perspectives but not at the expense of empirical analysis and historiography. In *Capital's Utopia*, Anne Mosher blends historiography with a theoretical argument about the industrial restructuring of the American steel industry in the late 19th century. Mosher provides more than a descriptive historical geography of place; she combines historical geography, labor history, and urban design to show how the social production of space in the model industrial town emphasized the social control of the worker. For historical geography to remain a relevant subfield of geography, it needs to continue to emphasize its unique perspective by continuing to present theoretical arguments and narratives based on conscientious examination and critical interpretation of primary documents.

### Relevance

As a subfield, historical geography is essential to the field of geography. In describing the relevance of historical geography, Donald Meinig argued that any understanding of place required historical understanding. He maintained that this understanding should not be used merely as a preface to, or simply as background for, a study. Instead, this historical understanding should be seen as a
thoroughly researched study of the cultural, economic, political, or environmental contexts of places. Despite its importance as a subfield of geography, historical geography is once again facing the question of relevance.

Since the 1950s and the quantitative revolution, historical geography has repeatedly had to prove its relevance. As geography became a positivist, nomothetic spatial science, historical geography was pushed from its central role to the periphery due to its connections with a descriptive, idiographic regional geography. The questions of relevance now facing historical geography stem mainly from the general blurring of disciplinary boundaries in the humanities and social sciences and a push by university administrators for more practical, marketable, and relevant skills. The methods of historical geography make it a useful tool in other subfields and disciplines. The results of the overlap with a variety of fields, including cultural geography and environmental history, are geographies with a historical focus. With this blurring of disciplinary boundaries, studies in cultural geography that focus on cultural practices and hegemony may use history in a few paragraphs that provide background or context but may not be theoretically informed historical geographies. These cultural studies, while theoretical, do not fully engage with the historical record to develop the narrative. Environmental history, on the other hand, has the historical record at its core. Adding a geographic dimension to this historical approach to nature produces theoretically informed historical geographies. The question of relevance may be a reflection of the current state of the academy, which emphasizes the profitability, productivity, and marketability of useful and practical areas of study. But the historical perspective will always be present in geography, and by publishing in journals such as Historical Geography and the Journal of Historical Geography, historical geographers can continue to raise the profile of historical geography within the field as a whole. As the historical perspective remains central to the study of geography, historical geography will continue to be essential to the intellectual vitality of geography.

Phil Birge-Liberman

See also Berkeley School; Cartography, History of; Clark, Andrew; Cultural Geography; Darby, Henry; Clifford; Environmental Determinism; Environmental History; Feminist Geographies; Historicism; Human Geography, History of; Humanistic Geography; Marxism, Geography and; Meinig, Donald; Mitchell, Don; Palimpsest; Quantitative Revolution; Regions and Regionalism; Sauer, Carl; Sequent Occupance; Social Geography; Whittlesey, Derwent

Further Readings


**HISTORICISM**

Historicism is the view that privileges time over space in social analysis. Some aspects of this view may be traced to the Christian eschatology of the medieval era and its linearization of historical time; however, in many respects, this notion—still implicit in much of social theory—had its origins in the 19th century. As the technological triumphs of the steamship and railroad relegated space to the background through massive time-space compression, the social sciences accordingly came to emphasize historicist approaches in which time was synonymous with growth, progress, change, and novelty. Historicism consists of a despatialized consciousness in which geography figures weakly or not at all, or, as Soja (1993) defines it, as “an overdeveloped historical contextualization of social life and social theory that actively submerges and peripheralizes the geographical or spatial imagination” (p. 140). Thus, Michel Foucault held that with the rise of modernity, time became equated discursively with change and fecundity, while space was relegated to the passive and static, a distinction that rests, of course, on an artificial and analytically misleading distinction between the two dimensions.

A central part of this process involved the birth of modern history as an account framed in linear, not cyclical, time (which was the norm in many societies), that is, by portraying time as an inevitable sequence from the past to the present to the future. Typically, historicist thought linearized time and marginalized space by positing the existence of temporal “stages” of development, anticipating modernization theory by more than a century. Historicism tended to portray the past as a progressive ascent from savagery to civilization, a trend made most explicit in British Whiggish accounts of history. This maneuver robbed the understanding of social change of any sense of contingency, framing the past as a train of events leading inevitably to the present. For the French utopian thinker Condorcet, for example, there were 10 distinct periods ranging from savagery to rule by science. Reading progress into the future, historians such as Herbert Spencer tended to portray history as an inexorable linear movement from simplicity to complexity, from primitiveness to civilization, from darkness to light.

In the same vein, historicists such as Georg Hegel, Karl Marx, and Arnold Toynbee offered sweeping teleological accounts of world history that paid little attention to space, human consciousness, or the contingency of social life. In his formulation, for example, Hegel transformed the ancient doctrine of perpetual change into a doctrine of the development of rational consciousness. Time, in this view, is not simply a measure of change but is synonymous with change, a view that became widely popular in 19th-century historical scholarship. Hegel’s work turned attention from eternal Platonic ideals to the concrete specifics of historical circumstances, even if the causal motor he attributed to this, the transcendent world spirit of reason, was itself profoundly Platonic in inspiration. Hegel specified three phases in history: (1) despotisms, in which very few were free (when the world *geist* was centered on the Middle East); (2) oligarchies, in which some were free (when the *geist* centered on Asia); and (3) democracies, in which most were free (when the *geist* had shifted to Europe). His work valorized the nation-state as the embodiment of the world spirit, culminating in the apex of Prussia. Marx, too, engaged in this practice by categorizing the historical record in a series of modes of production (slavery, feudalism, capitalism, socialism) that unfolded in the strict, unyielding course of history. Like other Enlightenment intellectuals, Marx, too, stressed the progressive character of history. This notion deeply influenced many historians, especially German historians, in the late
19th and early 20th centuries and had linkages to related schools of thought such as diffusionism. Social theory of the 19th century also drew heavily on Darwinian evolution for inspiration and legitimation, biologizing social relations and thus denying their contingency. The original theory of evolution as contingent and open-ended was erroneously usurped as a means of legitimating the notion of “progress” in the history of life, a simplistic, linear view of phyletic gradualism that was challenged in the 20th century. Spencer’s corruption of Darwinian selection—“survival of the fittest” was his phrase, not Darwin’s—drew heavily on modernist notions of progress and dressed historicism in a veil of pseudoscience. In 19th-century social theory, no distinction was made between “evolution” and “progress.” This line of thought persisted until the structuralism of the early 20th century jettisoned the synchronic in pursuit of universally ascribed atemporal structures.

Likewise, Enlightenment geographic thought, Occidentalist and Orientalist to the core, imagined a new, ostensibly universal geography with Europe positioned, naturally, in the middle, a project central to the works of Kant, Toynbee, and others. This task was accomplished by the deployment of linear stages representing universal historical time, in which Europe, naturally, represented the most advanced stage and distance from Europe testified to the nature of earlier, more primitive stages. Nineteenth-century textbook portrayals of the globe framed the Western geographical imagination around a series of continents, typically conflated with simplistic notions of race, that were hierarchically organized in terms of their alleged degree of temporal progress and, thus, their similarity to European and North American white nations. This schema gained respectability through its appeal to various forms of social Darwinism and environmental determinism. In this way did historicism eclipse space in the service of imperial thought. Beyond Europe was before Europe, a theme articulated over and over again in modernization theory and its current neoliberal variants.

In the 20th century, critics of historicism, for example, the philosopher Karl Popper, in his famous book The Poverty of Historicism, took the doctrine to task for its assumption that sufficient understanding of historical patterns and rhythms led to the ability to predict future events. This critique reflected the growing emphasis on contingency that increasingly permeated social thought and on the rejection of absolute “laws” of development and teleological views more generally. Nonetheless, elements of historicism continued to haunt doctrines such as modernization theory.

Post-positivist geography, which has aggressively reinserted space into social theory, has gone a great way toward overcoming the legacy of historicism. In this reading, the spatial cannot be reduced to an afterthought of the temporal, for all phenomena are necessarily both in nature. Simultaneously, as in Foucauldian readings that stress the primacy of social praxis, space and time are held to be deeply political, always tied up with existing relations of power. In this light, social changes are always contingent and can pursue a variety of trajectories over space.

Barney Warf

See also Eurocentrism; Geographical Imagination; Human Geography, History of; Orientalism

Further Readings


**HISTORIC PRESERVATION**

Historic preservation is the specialized, interdisciplinary study and treatment of historically significant movable and immovable objects, including landscapes. This term is used only in the United States; other countries prefer the word conservation to preservation and contextualize the meaning, as in such terms as urban conservation or building conservation. The chief concerns of historic preservation are to establish why certain
older places have acquired value over time and to identify methods that retain the historical integrity of building and landscape fabric. The overall goal is to ensure that changes to these places are made in a manner that does not impair their historical authenticity.

Within the discipline of geography, historic preservation is primarily associated with cultural landscapes, material culture, and the work of cultural geographers such as Henry Glassie, Fred Kniffen, and J. B. Jackson and secondarily with perception, behavior, place attachment, and the work of humanistic geographers such as David Lowenthal, Yi-Fu Tuan, and David Seamon. Geography’s contribution to historic preservation is typically restricted to helping define significance; it has not yet been a major player in discussions of policy, interventions, and management. Historic preservation therefore remains largely dominated by built environment disciplines such as architecture, landscape architecture, and planning. Since the 1980s, historic preservation has been recognized as a discipline in its own right, with unique theoretical and epistemological foundations, novel research methods, and its own university degree programs and practitioners.

Economics, sustainability, and place making are typical arguments for engaging in historic preservation. Examples include the National Trust for Historic Preservation’s highly successful “Main Street” program for downtown revitalization, the addition of pro-preservation measures in
“green” building standards such as LEED 3.0 (Leadership in Energy and Environmental Design) that consider energy used in production and construction, and the connection between preservation, sense of place, and well-being. The traditional approach of treating places and buildings as museums is still evident but increasingly unsustainable in economic as well as cultural terms.

In the United States, the National Park Service’s National Register of Historic Places nomination is the standard used to define historical significance, while the Secretary of the Interior’s Standards for the Treatment of Historic Properties prescribes specific treatments for the “preservation,” “restoration,” “rehabilitation,” and “reconstruction” of buildings and landscapes. Although these guidelines are only required for federal interventions, they have essentially become universal in their application due to their widespread adoption by local and state governments.

In recent years, there has been a shift toward the importance of sociocultural values in defining historical significance, but these ideas are yet to affect the day-to-day practice of historic preservation and are entirely absent from the criteria found in the National Register nomination. Critics charge that historic preservation remains a positivistic endeavor more concerned with the acquisition of “facts” than with fostering a sense of place and human flourishing.

Jeremy Wells

See also Architecture and Geography; Conservation; Cultural Landscape; Environmental Impact Assessment; Green Building; Jackson, John Brinckerhoff; Landscape Architecture; Landscape Interpretation; Sense of Place; Zoning

Further Readings


HIV/AIDS, G EOGRAPHY OF

The virus that causes acquired immune deficiency syndrome (AIDS), or acquired immunodeficiency syndrome, was first identified by scientists in 1983. Since then, the geographic origins of the virus have been hotly debated in the scholarly and secular communities. Recent studies by genetic scientists have indicated that HIV-1, the more virulent form of the virus that causes AIDS, can be traced to a closely related strain of virus, called simian immunodeficiency virus (SIV), that infects a subspecies of chimpanzees in Central Africa. It also happens that people in this region hunt chimpanzees for bush meat, leading scientists to believe that the virus may have passed from the blood of chimpanzees into humans through superficial wounds. Indeed, many believe that the virus has been prevalent among humans in remote, inaccessible jungle areas since the 1920s. However, in today’s globalized and highly interconnected world, the virus somehow managed to escape from this region into the wider world. There are two forms of this virus, HIV-1 and HIV-2. HIV-2 is restricted to the Guinea Highlands of West Africa, while HIV-1 accounts for the majority of AIDS cases throughout the world.

UNAIDS (Joint United Nations Programme on HIV/AIDS) estimates indicate that the number of persons living with HIV worldwide was 33.2 million in 2007. However as shown in Figure 1, sub-Saharan Africa continues to be the region by far most affected by the AIDS pandemic. In 2007, out of the 33.2 million people infected with HIV, 22.5 million were in sub-Saharan Africa. An additional 1.7 million people were infected with HIV during that year. During the same year, over 1.6 million people were estimated to have died from this syndrome in Africa. It is estimated that more than two out of three (68%) adults and

HISTORY OF GEOGRAPHY

See Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
nearly 90% of children infected with HIV live in this region, and more than three in four (76%) AIDS deaths in 2007 occurred there, illustrating the unmet need for antiretroviral drugs. In the 10 worst-affected countries, all of them in Eastern and Southern Africa, rates of HIV infection range from 16% to over 40%.

With reference to the geographic spread of the epidemic in Africa, John Iliffe, in his 2006 book titled *The African AIDS Epidemic*, masterfully synthesizes the plethora of studies that have been conducted from the 1980s to the present, tracing the geographic beginnings and spread of AIDS throughout the continent. Iliffe weaves together a fascinating story that attempts to explain the origins, nature, and spread of the virus from its detection in the early 1980s to its current progression throughout the continent. He places the origins of the disease somewhere in present-day Central Africa, from where it spread slowly to East Africa. Several other studies that have examined in greater detail the spatial-temporal trends of AIDS in Africa during the past 25 years show an escalating epidemic in Southern Africa and signs of a stabilizing or declining epidemic in East Africa. At present, Southern Africa remains the worst affected region in the world, with HIV prevalence rates in excess of 25%. Data in these detailed studies lend credence to the saying that “there is not just one epidemic in Africa, but

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**Figure 1** Adults and children estimated to be living with HIV in 2007

many.” West Africa and North Africa have consistently experienced lower rates than the other regions, although in some countries in West Africa, the epidemic is creeping up. Even within the other high-risk regions in Central, Eastern, and Southern Africa, some areas have lower rates than others. Thus, it is not just between countries that there are differences in the prevalence of HIV/AIDS, but there are differences between different areas and different groups of people within the same country. In spite of the spatial variations, the epidemic in Africa is largely driven by unsafe sex between men and women.

Outside Africa, rates of infection are generally low, but the numbers of infected people have been recently increasing dramatically in South and southeast Asia, notably in India and China. However, national HIV prevalence rates vary greatly between different countries. While the epidemics in Cambodia, Myanmar, and Thailand all show declines in HIV prevalence, those in Indonesia (especially in the Papua province) and Vietnam are growing. Although the proportion of people living with HIV in India is lower than previously estimated, its epidemic continues to affect large numbers of people (about 2.5 million people). In Asia, the HIV infections have been driven by both injecting drugs with contaminated equipment and unprotected sex. Overall in Asia, an estimated 4.9 million people were living with HIV in 2007, including the 440,000 people who became newly infected during that year. Approximately 300,000 died from AIDS-related illnesses in 2007 in Asia.

When the disease was first identified in North America and Europe, it was first thought to be a disease of homosexual men. In the early years, over 90% of cases were diagnosed in homosexual men. As a result, in the 1980s, HIV/AIDS was often described as “the gay plague.” As such, the early educational campaigns on safe sex targeted gay men. These have largely been successful in reducing the transmission rate among this population in North America and Europe. While the number of new infections of HIV/AIDS among homosexual individuals in North America is on the decline, the disease is now increasingly being spread through unprotected heterosexual sex. Recent UNAIDS estimates indicate that the total number of persons living with HIV is on the increase in North America and Western Europe.

This increase is due mainly to the life-prolonging effects of antiretroviral therapy and an increase in the number of new HIV diagnoses in Western Europe since 2002, combined with a relatively stable number of new HIV infections each year in North America. Overall, approximately 2.1 million people in North America and in Western and Central Europe were living with HIV in 2007, including the 78,000 who acquired HIV during that year. In the context of widespread access to effective antiretroviral treatment, comparatively few people (about 32,000) died of AIDS in these regions in 2007.

With the exception of Eastern Europe and Russia, elsewhere in the world, the HIV epidemics remain generally stable, and HIV transmission continues to occur in people at higher risk of exposure, including sex workers and men who have sex with men. In Latin America, the number of new HIV infections in 2007 was 100,000, which brought the total number of people living with HIV to 1.6 million in 2007. Adult HIV prevalence in the Caribbean was estimated at 1.0% in 2007. Prevalence in this region is highest in the Dominican Republic and Haiti, which together account for nearly three fourths of the 230,000 people living with HIV in the Caribbean. In Eastern Europe and Central Asia, an estimated 150,000 people were newly infected with HIV in 2007, bringing the number of people living with HIV in this region to 1.6 million, compared with 630,000 in 2001, a 150% increase over that time period. Nearly 90% of newly reported HIV diagnoses in this region in 2006 were from two countries: the Russian Federation (66%) and Ukraine (21%). Elsewhere in this region, the annual numbers of newly reported HIV diagnoses are also rising in Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Republic of Moldova, Tajikistan, and Uzbekistan (which now has the largest epidemic in Central Asia). The disease in this region is driven by intravenous drug use, which accounts for nearly two thirds of new infections (62%), while more than one third of new infections (37%) are attributed to unprotected heterosexual intercourse.

At the global level, although HIV/AIDS is overwhelmingly concentrated in sub-Saharan Africa, with epicenters in Eastern and Southern Africa, the future epicenter of the pandemic appears to
be the Asian continent, particularly India, China, and Russia, with a combined population of about 2.6 billion people in 2005. Should the epidemic aggressively spread to India, China, and Russia as it has done in Eastern and Southern Africa, the ramifications could be tragic for the region and the whole world. Consequently, examining the geography, the multiple dimensions, and the trajectories of HIV/AIDS vulnerability in sub-Saharan Africa may provide insights for targeting intervention and thus reducing the severity and impact of the disease, not only in Africa but also in other parts of the world where the disease is beginning to take hold.

Ezekiel Kalipeni

See also Disease, Geography of; Health and Health Care, Geography of; Medical Geography

Further Readings


**HOME**

*Home* is a concept that refers both to a specific space, such as a dwelling or one’s country, and to a sense of belonging—being “at home.” It is an idea that demonstrates the strong relationships between spaces, places, and emotions. Geographers have been interested in a range of aspects of home, including the house as home, material cultures of home, homelessness, home as a site of gendered relations, home and national identity, and the meanings of “home” to different groups.

The most basic meaning of *home* is a place to live. It can refer simultaneously to a current dwelling, a childhood home, or another place where loved ones live. This sense of home brings together ideas about physical space and the relationships that exist within and produce that space. The word *home* can be used to describe any form of dwelling, and in fact, other spaces are also described as home by people who feel a sense of belonging in them. For example, some people who are homeless describe the areas where they regularly spend time as “home” even if these are outdoors. However, in contemporary American society, home has been particularly associated with suburban developments of detached, or single-family, houses. Geographers study this association between particular urban forms, housing design, and familial relationships.

Feminist geographers have argued that this association between the home and particular forms of family life are rooted in the traditional gendered division of labor, in which men engage in paid work outside the home and women are responsible for housework and caring. The home is, therefore, a strongly gendered space, where men, women, and children may have different roles and experiences. This means that, as well as being a place of belonging, a home can be a site of exploitation and exclusion. For many women, the home can be a place of hard physical labor and, too often, the scene of domestic violence. It is also a workplace for many millions of domestic workers.

Meanings of home are not only differentiated along gendered lines. Life-course stages, class, and sexuality affect experiences and understandings of home, as does race/ethnicity. The African American writer bell hooks has argued that for poor women of color in the United States, the home is a site of empowerment, where strength can be gathered to fight the racism of the wider society. Geographers have also shown that *home* can take on a particular meaning for migrants. The house/home can be a site where the “homeland” is invoked and memories kept alive, for example, through interior decoration. This notion illustrates the links between the concept of home as a site of belonging at these very different scales.

Rosie Cox
HOMELESSNESS

Homelessness denotes an extreme and particular form of poverty characterized by a lack of secure housing. Homelessness is commonly divided into two groups: absolute and relative. Absolute homelessness refers to people who have no shelter at all and are forced to either sleep rough (outside, in stairwells, etc.) or stay in a temporary shelter. Relative homelessness includes many people who are able to attain some form of accommodation but for a variety of reasons are precariously or insufficiently housed. This includes those who are doubling up/couch surfing, those who are staying in a rooming house or residential hotel, and/or those who are under constant threat of losing their housing due to eviction. The definition of homelessness is politicized, as different definitions produce wildly varying estimates of the number of homeless as well as different courses of remedial action. The definition of homelessness is often either broadened or restricted, depending on the context and ideological disposition of the analyst, to include panhandlers, itinerant laborers, “squeegee kids” (who approach drivers with offers to clean their windshields), the disaster afflicted, refugees, and others. From a geographical perspective, where homeless people live and what they do there are particularly important to the definition of who is homeless.

Homelessness is not necessarily a permanent condition; people may move in and out of homelessness, often several times in their lives. Homelessness (whether absolute or relative) can be divided into transitional, chronic, and episodic forms. Transitional homelessness consists of brief experiences of homelessness, often due to family or economic disruptions, and is the easiest form to treat with preventive or emergency services. Chronic homelessness describes an experience of being homeless that lasts for lengthy periods and is interrupted only temporarily by “housed” experiences. Episodic homelessness refers to repeated forays in and out of homelessness; it is the most difficult form to address through government policy. Thus, public policy interventions tend to target the chronically homeless while neglecting episodic homelessness.

Early debates often counterposed an individual agency model against a structural understanding of the causes of homelessness. Individual/agency explanations of homelessness focus on life-changing events (family breakup, domestic violence, disability) and/or personal failings (mental health, addiction, delinquency, poor job skills) in predicting homelessness. Structural explanations, on the other hand, consider capitalist housing and labor markets as systems that produce poverty and homelessness. The foci of research on the structural causes of homelessness include economic restructuring, mass unemployment, rent gouging, gentrification, deindustrialization, deinstitutionalization, housing policies that benefit homeowners at the expense of renters, and the privatization of social housing.

Research has sought to provide more holistic perspectives that integrate the structural and agency models. Economistic work in this area, for instance, finds that while combinations of individual-level variables predict who is most susceptible to homelessness in a given place, local housing and labor market conditions determine the number and proportion of the poor that actually end up homeless. However, this work has been criticized for treating individual-level risk factors as exogenous to housing market conditions, when the evidence suggests that the two are in fact linked. For example, the research suggests that depression and substance abuse are as much an outcome of homelessness as their cause and that

See also Gender and Geography; Homelessness; Housing and Housing Markets; Neighborhood; Sense of Place

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the move out of homelessness is a major factor in reducing both problems. To counter these shortcomings, homelessness research has moved to examine the pathways into and out of homelessness, in which the various risk factors and life situations make certain people who are more susceptible to homelessness interact with the structural processes occurring in labor and housing markets.

A pathways approach contributes to our understanding of the spatiality of homelessness. Geographers have explored how life events intersect with public policies regarding shelter use, time limits, and the level and criteria for accessing welfare state benefits to produce distinct geographies for homeless men and women. Geographers have also examined the importance of context in understanding the myriad homeless and mental health geographies produced through interactions between economic restructuring, deinstitutionalization, policy agendas, and community care networks. There is also now research demonstrating the specific problems and complexities of suburban and rural homelessness. This is of particular importance for policy because of the clustering of shelters and services for the homeless in downtown areas and the relative lack of such services in outlying areas.

The concepts of visible and invisible homelessness add another dimension to the lived experience of homelessness. Visible homelessness is characterized by engaging in public view in many activities of everyday life, including but not restricted to sleeping rough, panhandling, and washing. The visible homeless are disproportionately male and single. This form attracts the most media and policy attention and is in turn the subject of the most government intervention.

A homeless person rests on a bench in Central Park. According to the Coalition for the Homeless, the number of homeless people in New York City has increased by two thirds over the past decade. More than 36,000 homeless people sleep each night in the New York City municipal shelter system. Source: Morguefile.

Research has shown how masculinized service provision and public spaces have served to further marginalize those women who are among the visible homeless population. Invisible homelessness, in which women, children, and immigrants disproportionately feature, provokes much less public concern and fewer policy solutions despite its continued growth. The work on invisible homelessness builds on feminist scholarship that demonstrates how homeless women and
children are doubly marginalized in their exclusion from both public space and essential homelessness services geared toward the visible homeless. Increasingly, the visible homeless are also often subjected to enumeration and “street sweeps,” in which particular individuals are removed from public view. Current policy approaches in the cities of Western nations have been found to be inadequate for dealing with the burgeoning populations of invisible homeless in large cities, both in downtown and in peri-urban areas.

Finally, it must be noted that homelessness is an acute and growing problem in both developed and developing countries, with implications for emerging geographies of urbanization, uneven development, social attitudes, and political cultures. However, it is even more difficult to define and to determine the extent of homelessness in developing countries, where the problem overlaps with the issue of informal (squatter) settlements and where government policy is mostly hostile and punitive.

Jeff May and Alan Walks

See also Home; Housing and Housing Markets; Poverty; Social Justice
Hou Renzhi was singularly influential in shaping the modern study of geography in China, leading its transformation from a tradition of chronicling to a systematic approach. Hou built his reputation by publishing important work on historical Beijing, the historical archaeology of the Huang Ho River basin, and classical Chinese geographical thought. His historically based geographical contribution to the development of the modern city of Beijing included redevelopment of irrigation and water conservation systems and planning for Tiananmen Square.

Hou was born in Hebei Province and holds a BA in history (1936) and an MA in historical geography (1938) from Yenching University, predecessor institution to Peking (now Beijing) University. Hou was an instructor at Yenching and elsewhere during the Japanese occupation of China, before joining H. C. Darby in 1946 to study historical geography at Liverpool University. He completed his doctorate in 1949 and returned to Yenching University just days before the founding of the People’s Republic of China.

He was appointed professor and chair of the department of geology and geography with the reorganization of Yenching as Peking University in 1952, and from 1962 to 1966, he served as deputy director of studies at Beijing University (a position akin to vice provost for academic affairs). During the Cultural Revolution in China and the years following it, from 1966 to 1978, regular teaching at the university was suspended. The Red Guards criticized Hou, placed him under house arrest, and beat him, and he spent 1969 through 1971 in a Jiangzi Province labor camp. When Hou was able to resume his research, he undertook pioneering fieldwork on historical archaeology and the historical geography of China’s deserts while continuing work on Beijing’s historical geography.

Appointed professor and chair in the newly separate department of geography in 1978, Hou led the rejuvenation of the program and the university. From 1983 to 1987, he directed the historical geography research group at Beijing University and then became director of doctoral studies. In 1980, Hou was visiting professor at...

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the University of British Columbia, the next year a Fulbright Scholar at the University of Illinois, and in 1984 a Luce Fellow in urban planning at Cornell University. Hou was also a member of the International Geographical Union Commission on the History of Geographical Thought (1984–1992). For some 30 years, he served as vice chair of the Chinese Society of Geography. Hou is a long-time member of the Chinese Academy of Sciences, and he was still engaged intellectually with geography as of the writing of this biographical essay.

Among his many honors, Liverpool University granted Hou an Honorary Doctorate of Science in 1984. In 1988, Beijing University honored him for his then six decades of service by publishing a collected volume of his works covering diverse topics such as regional historical geography, historical urban geography, desert history, and the history of geographical thought. The American Geographical Society honored Hou in 1999 with the George Davidson Medal for exceptional research contributions to geography.

Joseph S. Wood

See also Historical Geography

Further Readings


Housing and Housing Markets

Housing is, in general terms, a tangible structure where people live. It provides protection from the elements and supports basic physical human needs such as a place to eat and sleep. However, the importance of housing is broader than its physical functions. Housing also provides the space for family interaction—the basic building block from which society is formed. For humankind, housing is as basic a need as is water or food.

Housing, examined from a more complex approach, is a commodity with unique attributes and peculiarities. First, it is produced and consumed in the same location, essentially exhibiting spatial fixity—an attribute uncommon in other commodities. Unlike other consumptive goods, traditional housing is fixed in space and cannot be moved to another location. In other words, the production and consumption of housing depends on road networks that make it accessible to other areas. A housing unit is both a commodity and an investment. Housing as a consumptive good helps define the quality of life or socioeconomic standing of its consumer. Housing is generally the primary investment for many families and can transfer wealth in the form of inheritance to subsequent generations. In urban areas, the housing unit is the primary building block of neighborhoods.

Neighborhoods

Neighborhood can be defined in various ways. A neighborhood can be an area where the housing units are similar in design or type, a geographical area with a distinguishable character or physical feature, or a relatively homogeneous social unit formed by religious, ethnic, or socioeconomic ties. Thus, a neighborhood might share various characteristics throughout a determined geographical area that might delineate a specific type of subdivision of the housing market or submarket. Therefore, housing is strongly influenced by neighborhood characteristics that might influence its value.

Housing Configuration

The housing market consists of available housing units for sale, known as housing stock, and families willing to buy those housing units. Housing stock can be distinguished by attributes such as design, type of structure, geographical area, and physical characteristics. These attributes vary across space and can form a specific housing
submarket. Families base their decision on acquiring a housing unit according to what is a desirable standard of living and according to its socioeconomic characteristics. Therefore, the final price is the product of the interaction between these two agents: available housing units and families, or sellers and buyers.

Housing is both a consumer good and an investment, and it is subject to the basic economic law of supply and demand. Housing demand has two origins: families and investors. As consumers of housing, families are interested in housing primarily as a commodity. They focus on the internal and external characteristics of the physical housing unit, such as the number of bedrooms and bathrooms, the internal and external dimensions of the structure, the neighborhood characteristics, the geographical location, and public service provision. Families as buyers generate variations across the housing market in which some neighborhoods might, for example, suit a young urban professional, a double-income couple without kids, or a single parent with children better than others. Speculators and landlords are primarily interested in housing investment opportunities as in any other investment opportunity.

Defining a housing market is not a simple task, although housing units within a specific geographical area are, in general terms, comparable with other units in the same geographical area. Housing markets depend on multiple variables, such as demographics and purchasing power, which are constantly changing. For example, the phenomena of the baby boom generation and the increase in the number of empty nesters are demographic changes that can influence a specific housing market and change its locational preference from a suburb to a southern, sunny location. The rearrangement of the housing stock to satisfy the demand might trigger neighborhood changes or
changes in land use. Thus, as the housing supply is subject to a market economy, it is necessary to recognize the influence of the developer in the process of defining a greater geographical area as a housing market in which the developer can produce and distribute resources.

**Housing Markets**

As with any other consumer goods, housing markets are the results of the interaction between seller and buyer. The demand for a housing market is based on the same characteristics that influence the demand for other goods—namely, employment, demographics, and income. The national level of employment is an indicator of income; when unemployment increases, housing purchases might decrease. The composition, distribution, and movement of the population are other factors that can influence demand in the housing market. For example, high interest rates can slow down home acquisitions, while low interest rates may increase home acquisition, especially during an economic recession. At the same time, unemployment and lower income triggered by a severe recession may lead to a collapse of the housing market, especially when mortgage lenders withdraw from the market.

Besides the buyer, other agents in the housing market include landowners and developers as well as financial institutions and governmental institutions. However, mobility enables people to redefine the geographical limits of housing and labor markets. Thus, employers also play a role in the housing market. Nonetheless, the mortgage credit market is fundamental for both the developer and the buyer. The mortgage credit market is an important force in national and local processes in the demand for housing.

**Housing Market Problems**

In the United States and other capitalist economies, housing is seen as similar to any other commodity that can be sold and purchased in the market without intervention from the state. It is widely believed that in a market economy, the pursuit of individual interest promotes collective well-being. Unfortunately, very often, the housing market fails to provide equal access for all socioeconomic groups, especially minorities and buyers with lower economic wealth or limited credit. The scarcity of affordable housing is a factor contributing to overcrowding and retention of lower-quality housing stock. However, low income is just one of the problems for some families trying to access housing. Housing discrimination by sellers and lenders was overt during much of U.S. history and continues to be a problem today.

Sometimes the state intervenes to stimulate the housing market. After World War II, the federal government established the Federal Housing Administration (FHA), making loans affordable for thousands of families to purchase new houses. However, the FHA favored the construction of single-family dwellings in the suburbs over the rehabilitation of old multifamily buildings in the city. Therefore, through a legal framework, the state delineated a public policy that resulted in barriers to affordable housing for minorities, with a negative impact on society.

*Jose R. Diaz-Garayua*

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**Further Readings**

Housing Policy

Housing policy includes formal laws and regulations that directly affect the construction, maintenance, and use of housing. While housing policies vary by country, they generally aim to meet both physical and social goals. Differences in national policies reflect how much faith a country has in the market to provide housing for its people and under what circumstances the state will intervene. For example, the United States first intervened in the market in response to the Great Depression, introducing new financial instruments and incentives to help jumpstart the economy by making it easier for people to buy homes. In comparison, the United Kingdom and many European countries began investing in resources to support the production of housing for lower-income working families in the late 1800s, in an effort to improve the poor living conditions resulting from rapid industrialization. In most communist states, the market was supplanted by government development programs and redistribution strategies. Poor and developing countries with limited private investment historically are more likely to rely on external agencies for housing assistance. In all cases, an outcome of interest to geographers is the spatial patterns and uneven development that result from housing policy or the absence of it.

Housing goals may be differentiated into physical and social ones. Physical goals may be loosely defined as those concerned with the quantity and quality of housing environments. Social goals, in contrast, focus on housing affordability and equality of access.

Physical Goals

Policy sets standards that public officials use to regulate the development and use of housing. Most common are building codes to ensure sound construction and occupancy standards to prevent overcrowding. Depending on the country, standards may be national or, as in the United States, may be delegated to state and local jurisdictions to develop and enforce. While this arrangement allows for specific standards to be adapted to fit different climates and conditions, it also means that the rules guiding housing production are uneven. Still, even when standards are uniform, decisions about housing development often are not, since they are subject to human judgment.

The basis for most housing policy is health and safety. During the industrial period, for example, social reformers in the United Kingdom and the United States pushed for standards to ensure sufficient light, air, space, and sanitation in housing built to accommodate the large influx of workers to urban areas. More recently, attention has been paid to eliminating lead-based paint, reducing accidents and falls, and improving air quality inside homes, because these conditions not only contribute to disease and injury but also are expensive for families and government.

Land use restrictions also affect housing. Many countries employ zoning, a formal legal policy that designates how land can be used within a jurisdiction to produce public benefits. A common strategy has been to reduce threats to health and safety by separating the places where people live from the locations of activities that generate noxious odors or noise. Perhaps taken to an extreme, zoning has also been used to exclude some uses from a community by requiring a minimum lot size for homes to be developed, ensuring a low-density and presumably healthier environment. Industrial uses as well as higher-density and/or lower-cost housing are among those that have been excluded through the use of zoning. These practices, often referred to as exclusionary zoning, are often linked to uneven development and more recently with urban sprawl in the United States and Europe.

Social Goals

Many developed countries and developing countries promote owning rather than renting as the preferred form of tenure, primarily because it can generate wealth; most agree that a home is a good long-term investment, since housing values usually increase ahead of or at least keep even with inflation. Incentives include tax benefits to owners and even grant programs to help lower-income households buy their first home. However, what is more common is government policy to ensure that sufficient credit is available to keep supply and demand in sync. This can include changing the flow of money via interest rates as well as...
finding ways to ensure that purchasers have access to capital, usually in the form of mortgage funds. While such resources make it easy to borrow a significant portion of the home’s value and then pay it back by amortizing the loan over a long period of time (e.g., 30 years), mortgages tie up money and put banks at risk. To offset this risk, many countries have made it easier for financial institutions and investors to buy and sell mortgages. These “secondary markets” create opportunities for more investment, which in turn can help increase a country’s gross domestic product as well as consumer spending.

In many countries, housing policy also aims to solve perceived social problems. Shortage of housing for socially disadvantaged populations is the problem most frequently addressed; the response may include building publicly owned, low-cost housing for specific populations—for example, people who are aging or with disabilities, low-income families, the homeless—or providing some form of subsidy to help tenants afford privately owned rental housing. Some countries even guarantee a right to housing to ensure that every person has at least some minimal level of shelter. In contrast, policy to transform squatter settlements and shantytowns into formal housing raises questions about what housing rights people have when they do not own land.

Housing policy also has been devised to change uneven development and other spatial patterns that are deemed problematic. For example, a growing concern in the United States, the United Kingdom, Europe, and Australia is the “social exclusion” of poor people, who are often concentrated in substandard social housing in urban areas and isolated from much of the rest of society. To change this situation, housing policies were created to permit governments to demolish these communities and replace them with new, mixed-income developments on the premise that this will help poor people become included in society and improve their situations. Similar assumptions underpin efforts to promote racial and ethnic integration. Still, in most countries, the pattern of housing development continues to be relatively segregated by race and ethnicity as well as by income.

Janet L. Smith

See also Ethnic Segregation; Filtering; Home; Homelessness; Housing and Housing Markets; Inequality and Geography; Neighborhood; Public Housing; Racial Segregation; Urban Policy; Urban Spatial Structure; Zoning

Further Readings

HOYT, HOMER
(1895–1984)

Homer Hoyt pioneered academic and applied real estate market analysis in the mid 20th century. Academics know him primarily for his sector theory of urban land development. Practitioners also know him for advances in procedures that came about from his consulting and appraisal services, including his use of economic base calculations as input measurements to estimate the current and projected demand for commercial and residential real estate. Hoyt innovated procedures for estimation of the highest and best use of a site (“a site looking for a use”) and for analyzing location criteria for a real estate activity (“a use looking for a site”). A third legacy is his contributions to the development of institutions important to land economics and real estate, including the Federal Housing Administration, and his endowment of the Homer Hoyt Institute. Hoyt’s legacy continues through his $8 million gift on his death in 1984 to the Homer Hoyt Institute, which today sustains Homer Hoyt’s legacy by supporting land economics and real estate research and by providing educational forums for academics and practitioners in the field.

Hoyt was born in St. Joseph, Missouri, in 1895. In his early years, Hoyt lived in a tent near Kansas City with his mother, Elizabeth, who
homeschooled him. She helped him pay the college tuition fee of $15 per year at the University of Kansas, from which he graduated in 1913 at the age of 17. He won a fellowship from the University of Chicago, where he earned a JD in 1918. In 1917, he accepted a position as an economics instructor at Beloit College in Wisconsin.

At the start of World War I, Hoyt was pulled out of academic life and into public service as an economist for the War Trade Board in Washington, D.C. This pattern of employment would repeat throughout his life. Following the end of the war, he accepted a position as professor of economics at the University of Delaware. In 1920, he declined a professorship in economics at the University of Michigan, working instead as a statistician for the American Telephone and Telegraph Company (AT&T) in New York City. Bored at AT&T, Hoyt returned to academia at the University of North Carolina at Chapel Hill (1921–1923) and then at the University of Missouri at Columbia (1924–1925).

In 1925, Hoyt again left academia for the private sector and public service. Hoyt thrived as an independent scholar. He became a real estate broker and consultant based in Chicago from 1925 to 1934, during which time he completed his PhD in economics at the University of Chicago (1933) and published his influential dissertation *One Hundred Years of Land Values in Chicago: 1830–1933* (reprinted in 1970). Hoyt’s dissertation provided the foundation for socio-economic models of neighborhood change. He documented empirically his hypothesis that real estate values reflected sociodemographic indicators, particularly income and social standing. At the time, race was highly correlated to income and social status and so could substitute for income in thematic map overlays.

Hoyt pioneered procedures known today by geographers as the *map overlay*, an innovation typically credited to the urban planner Ian McHarg. However, McHarg’s work was executed nearly 30 years after Hoyt used map overlays in his dissertation and long after Hoyt pioneered map overlays for business decision making and public policy analysis at the Federal Housing Administration (FHA). Hoyt pioneered rigorous economic models to understand and explain the market forces that create the spatial pattern of urban land use and urban land values. This understanding is a requirement for anticipating changes in land values and land use, which are necessary for business decisions and urban planning. Hoyt was the principal housing economist for the FHA (1934 to 1940), which was established under the National Housing Act. The mandate of the FHA was to revive the collapsed U.S. real estate market and to promote new housing construction. During this period of public service, writing as an independent scholar, Homer Hoyt published two important books: *Principles of Real Estate* (1939; 7th edition published in 1978), coauthored with Arthur Weimer (and later George Bloom), and *Structure and Growth of Residential Neighborhoods in American Cities*, a report for the FHA (1939; reprinted in 1971).

The prevailing urban growth theory of the time was Ernest Burgess’s hypothesis of 1927 that cities grew as a series of concentric rings expanding outward from a central core. In the Burgess model, each ring was composed of a specific land use, such as industry or worker housing. Hoyt’s sector theory of urban development challenged Burgess’s model. His sector theory held that urban spatial patterns are wedge-shaped sectors (not rings) radiating from central nodes, such as the city center, along transportation corridors. Each sector is distinct from the others, and each is fairly homogeneous as regards land use. Sectors, according to Hoyt, were dominated by workers’ housing, high-income housing, commercial land use, industrial land use, and so on. Especially important to Hoyt was the social status of the residents of the various sectors as well as the physical geography of the sector. He correlated high-social-status residential areas with higher elevations. Higher-status housing sectors tended to arise among sectors offering unconstrained growth outward toward open, uncongested spaces. In contrast, Hoyt observed that low-income sectors were more likely to have comparatively lower elevations, including flood plains, and to be unable to accommodate future development.

Hoyt was director of research for the Chicago Planning Commission from 1941 to 1943, during which time he published his 1943 *Master Plan of Residential Land Use of Chicago*. He then became director of economic studies for the Regional Plan Association in New York City (1943–1946), for
which he wrote *Economic Status of the New York Metropolitan Region in 1944*. While executing his work for New York, Hoyt agreed to be a visiting professor of land economics at the Massachusetts Institute of Technology and also at Columbia University.

Hoyt’s sector theory proved useful in understanding the dynamics of urban growth and was put to use in the post–World War II United States. The mid 20th century was a period of rapid suburban expansion; cities were being shaped by private decisions regarding where to build housing tracts and to which socioeconomic group the housing should be targeted. Private decisions were also being made on where to develop regional shopping centers. Public decisions were being made on where to build public infrastructure such as streets and expressways. Hoyt’s map overlays were put to good use in improving these private and public real estate decisions. As a consultant, Homer Hoyt became very wealthy.

Hoyt Associates was founded in Larchmont, New York, at the end of World War II and relocated to Washington, D.C., in 1953. The consulting firm specialized in land economics, demographic studies and real estate appraisals, and location advisory services. Its clients included country and city governments and private investors. Hoyt forecasted the rapid postwar expansion in population and in suburbanization, and he advised local governments to put planning regulations in place ahead of this rapid development. By the early 1970s, Hoyt Associates had performed market analyses for over 200 shopping centers throughout the United States. In 1974, Hoyt shifted his entrepreneurial interests, applying his models to guide his own real estate investments. His endowment to the Homer Hoyt Institute was the acquisition of a barrier island off the coast of St. Lucie County, Florida, which was later sold to the State of Florida to be turned into a turtle sanctuary, and the proceeds were used to sustain the Homer Hoyt Institute (www.hoyt.org).

*Grant Thrall*

**See also** Chicago School; Housing and Housing Markets; Neighborhood; Real Estate, Geography and; Urban Geography; Urban Spatial Structure

### Further Readings


**HUMAN DIMENSIONS OF GLOBAL ENVIRONMENTAL CHANGE**

Studies of the human dimensions of global environmental change explore the social causes and consequences of large-scale environmental transformations. These include, for example, climate change or global warming, stratospheric ozone depletion, acid rain, land use changes such as wetlands loss and deforestation, biodiversity loss, and changes in the abundance, diversity, and productivity of marine populations. Widespread local-scale changes, such as in water access or water quality, can be considered global environmental problems because of the magnitude of their impacts on society. Human actions are considered to be the central force behind all types of global environmental change, whether it is...
through population growth, resource extraction, energy consumption, urbanization, technological change, changes in consumer demands, or shifts in attitudes, lifestyles, and beliefs. Central to all research on the human dimensions of global environmental change is the idea that human activity is changing natural, life-supporting processes and that scientists, policymakers, and the public need to pay attention to what these changes mean for society and its future sustainability.

Human dimensions research encompasses a broad array of issues, discussed in this entry, including (a) the social, economic, political, cultural, and/or demographic drivers of global environmental changes; (b) the impacts of these changes on human systems at scales ranging from the global to the local; (c) the vulnerability of different sectors, regions, and social groups to these changes; and (d) the responses to these changes, including both adaptation to the effects of global environmental change and mitigation of the causes of these changes. Human dimensions researchers are also keenly interested in issues of governance, equity, and social justice and the role of discourse in influencing how global environmental problems are defined and addressed.

The Drivers of Global Environmental Change

Research on the drivers of global environmental change documents how human activities contribute to various types of large-scale environmental changes. This work includes investigations of human activities that affect the entire Earth system. This work also entails study of the role of human activities in contributing to cumulative local changes that influence the global environment through the magnitude and distribution of their effects. Examples of systemic-focused research include the study of present and projected future consumption of fossil fuels on a global scale, with a focus on how this contributes to climate change, or the study of how international regulations of chlorofluorocarbons are implemented and the consequences of this implementation for stratospheric ozone depletion. Research that emphasizes the cumulative effects of local-scale changes draws attention to activities that are occurring on a worldwide basis, such as the release of untreated sewage into natural waterways, rapid urban spatial expansion, and overfishing of large predatory species, and explores how these activities affect global water systems, global land use patterns, and species survival rates, respectively.

Study of the human drivers sometimes entails modeling the physical processes of environmental change while incorporating social factors such as population growth, energy consumption, or per capita income. This work may also involve the empirical documentation of global-scale changes, based on remote sensing analysis of changing land use patterns or statistical analysis of temperature records in urban areas. The socioeconomic causes of cumulative types of local environmental changes are also emphasized, such as the economic causes of overpumping of groundwater for irrigated agriculture, which, in turn, contributes to salinization and large-scale land degradation.

The Impacts of Global Change

Research on the impacts of global environmental change explores how various types of changes may influence coupled social-ecological systems. Such impacts research often has a sectoral emphasis, focusing on how changes such as higher temperatures, reduced precipitation, or more frequent extreme events associated with climate change may affect specific sectors of an economy, such as agriculture, energy, transportation, health care, or tourism. Sectoral approaches typically document impacts in economic terms, for example, by calculating the effects of environmental change on total crop production, energy costs, infrastructure investment levels, the cost of asthma treatment, or the number of visitors to a tourist destination.

Such research may also document the effects on ecological processes, or what is often referred to as ecosystem or environmental services. Impacts research may sometimes have a regional focus, looking at how a political, economic, or ecological region, such as a nation-state, coastal city, or river delta, may be affected by global environmental changes, again with an emphasis on the prediction and quantification of impacts in economic or ecological terms. In the case of a river delta, for example, an impacts-oriented study...
might document the economic consequences of mangrove destruction, due to both upstream water diversions and sea-level rise, on the local shrimp industry, as well as the ecological consequences for biodiversity.

### Vulnerability

Vulnerability research examines how and why some groups and individuals are disproportionately exposed to the negative effects of global environmental change and which factors influence their capacity to respond to these changes. Vulnerability research often emphasizes the contextual factors that lead to the negative outcomes of a particular process of change. These contextual factors include economic, social, cultural, political, environmental, and institutional conditions that either constrain or enable effective responses to various types of environmental stresses. Wealth, education level, social capital, access to political power, and cultural worldview are among the many individual attributes that affect these responses. Variations on vulnerability approaches include resilience frameworks, which focus on how society anticipates and plans for future changes, and capabilities, assets, and livelihoods approaches, which emphasize the factors that constrain or enable people to pursue outcomes that they value.

In addition to the emphases on vulnerability and the capacity to respond to single drivers of global environmental change, researchers are increasingly interested in vulnerability to multiple stressors. Multiple-stressor approaches recognize that individuals and communities are often subjected to more than one ongoing process of global change. Recognition of multiple stressors is seen as key to understanding why some regions, individuals, or groups are more able or less able to adapt to global environmental change. These approaches typically combine investigation of vulnerability to changing environmental conditions with an examination of other stressors such as disease, warfare or conflict, and economic disruptions. Research in Southern Africa, for example, shows how climate change, rapid urbanization, the spread of the human immunodeficiency virus/acquired immune deficiency syndrome, and political conflict are all creating stresses on socio-ecological systems.

### Adaptation

Research on multiple stressors has also helped identify points of intervention for responding or adapting to multiple global change processes. Adaptation research explores the actions or strategies taken by an individual, household, group, firm, public institution, or governing body either in anticipation of or following exposure to some type of environmental change. Adaptations can take the form of decisions, policies, or behaviors, with the objective of adjusting to new environmental conditions or new types of environmental stresses.

Actions that are taken to reduce the immediate negative outcomes are sometimes referred to as coping strategies. Successful coping strategies are in many cases a prerequisite for successful adaptations that reduce long-term vulnerability to shocks and stressors. However, coping strategies may in some cases undermine adaptive capacity if, for instance, they involve selling productive assets or withdrawing children from school.

Adaptations can also entail actions taken in anticipation of exposure to new conditions. Anticipatory responses may include the purchase of insurance, diversification of crops or investment portfolios, improvements in infrastructure, creation of protected areas, expansion of livelihood options, and so on. They may also include making investments in infrastructure, education, social welfare and job training programs, or livelihood diversification. Such responses are often based on assessments of risk and strategies for social, economic, or environmental planning. Research on adaptation also stresses the significance of actions and interventions made at different scales. External interventions, for example, federal government training and education programs, humanitarian aid from international organizations, suspension of interest payments on debt by international banks, structural adjustment programs, and other actions, may either facilitate or hinder adaptation.
Mitigation

Research on mitigation focuses on policy measures and technological responses that are intended to slow or halt the processes of global environmental change. This notion of mitigation differs from how the term is used in the geographic literature on hazards, where mitigation typically refers to reducing vulnerability and the likelihood of disaster. Within the human dimensions literature, mitigation research focuses on ameliorating the causes of various types of changes, such as reducing greenhouse gas emissions from automobiles or slowing the pace of tropical deforestation (which is also frequently connected to mitigation of carbon emissions).

Topics for mitigation research include emissions trading schemes, carbon taxes, and green development mechanisms. It also includes research on changes in sociotechnical systems, including shifts to alternative energy technologies and the implications of these shifts for social, economic, and environmental sustainability. Mitigation research also explores local political organizations and social movements around environmental issues. Among the most prominent topics are studies of how urban local governments have agreed on carbon emissions reductions. Mitigation research is often tied directly to the issue of sustainability based on the ethical understanding that mitigation is needed to ensure that the activities of the present generation do not undermine the ability of future generations to meet their needs.

Environmental Governance

The issue of governance is an important theme across all facets of research on the human dimensions of global environmental change. Research on governance focuses on questions of how resources are managed, how regulatory frameworks and institutions shape the behavior of individual actors, and how these actors may, in turn, affect institutions. Much attention within this area has been devoted to understanding how neoliberal (i.e., free market) approaches to resource management have contributed to the pace of environmental change. Privatization of common lands under neoliberalism, for example, is connected to an increased pace of conversion of forest land to agricultural uses, leading to soil degradation, loss of biodiversity, and other effects.

Human dimensions researchers also recognize that efforts to both adapt to and mitigate the causes of global environmental change may require new types of governance structures or new types of cooperative agreements. For example, adaptation to sea-level rise may eventually require relocation of populations from low-lying coastal areas. Yet existing political and economic structures often reinforce migration of new residents into these vulnerable areas, based on the assumption that sea walls and other technological interventions will provide protection. Coastal relocation may ultimately require new types of governance structures that are more regional in scope. The regulation of fisheries on a global basis to ensure species survival represents another situation where new types of cooperative governance may be appropriate.

Equity and Social Justice

Issues of equity and social justice are also becoming increasingly prominent in research on the human dimensions of global environmental change. A growing awareness of the equity issues surrounding global environmental change is not surprising given the widespread recognition that the effects are likely to be highly uneven and are likely to create winners and losers. Some individuals, households, communities, or regions will experience significant negative effects, such as the loss of life and property due to climate extremes, a rise in skin cancer due to stratospheric ozone depletion, the loss of agricultural productivity, increased water stress, and so on, whereas others may experience only minor negative effects, and still others may experience net benefits, such as lower winter-heating costs due to warmer temperatures, a longer agricultural growing season, increased forest productivity, or an expansion of tourism due to land use changes. Equity and justice issues arise in part because these differential effects are not randomly distributed but often systematically harm groups that are already economically or politically marginalized. For example, in many developing world cities, households living in informal housing rely on private water vendors
for their water supply. These households are more likely to experience the negative effects of water supply shortages (e.g., dramatic price increases) than wealthier households, which are more likely to be served by municipal water suppliers.

In addition to inequities regarding environmental impacts or vulnerability to environmental change, geographers studying human dimensions have given much attention to equity in the mitigation of these changes. With regard to climate change, for example, questions of equity in mitigation arise regarding who pays the costs and who bears the burdens associated with emissions reduction policies. These issues are complicated by differential responsibility for historical versus present and future emissions. While most greenhouse gases that are present in the atmosphere today are the result of historical and current activities in industrialized countries, future emissions will increasingly reflect activities in developing countries, especially China (which in 2006 overtook the United States as the world’s leading emitter of carbon dioxide), as these countries increase their industrial output and adopt lifestyles that are more energy consumptive. Broader issues of intergenerational equity are also in play with respect to climate change mitigation, including obligations of fairness, maintaining a wide range of options, and ensuring quality of life. The ethical dimensions of environmental change are thus becoming more prominent in human dimensions research.

Environmental Discourse

Finally, human dimensions researchers are increasingly interested in the role of competing discourses in influencing how environmental issues are defined and addressed. Discourses include assumptions, values, judgments, and contentions that provide the basic terms for analyses and debates, influencing both agreements and disagreements. More important, discourses carry political weight and reflect the underlying power structures: Proponents of some discourses have more power, thus exerting a greater influence not only on how specific issues are presented and understood but also on which responses are prioritized and pursued. In relation to global environmental change, questions of discourse arise not only around definitions of global environmental change—whether the changes are truly global—but also around the approaches used to evaluate and address these changes.

The discourses on global environmental change can be organized into three categories, biophysical discourses, human-environment discourses, and critical discourses, each of which is based on a particular approach to science. Biophysical approaches frame environmental problems as biophysically based concerns that need to be addressed through both technological innovations and international commitments to reduce, limit, or suspend activities that lead to environmental changes.

Human-environment discourses, which are prevalent in much of the literature discussed above, emphasize the integral connections between human and natural systems and the importance of connecting biophysical and social processes to understand drivers, impacts, and vulnerabilities. Proponents of human-environment discourses also emphasize adaptation and social learning as responses to environmental change and stress the formation of partnerships among governments, private sector actors, civil society, and academia.

While the biophysical and human-environment discourses stress the environmental aspects of global environmental change, critical voices argue that the focus should be placed on the political, economic, moral, and cultural dimensions. Based on structural and political analyses, including those pertaining to political economy and political ecology, adherents to critical discourses emphasize that the outcomes of environmental change are largely a function of the wider social, economic, and political forces that create and perpetuate inequalities. Recognition of these multiple and competing discourses is vital to understanding the breadth of research on the human dimensions of global environmental change.

Robin M. Leichenko and Karen L. O’Brien

See also Adaptation to Climate Change; Anthropogenic Climate Change; Climate Change; Climate Policy; Coupled Human and Natural Systems; Cultural Ecology; Differential Vulnerabilities to Hazards; Ecological Footprint; Environmental Discourse; Environmental History; Environmental Impact Assessment;
Human Ecology

The field of human ecology studies and analyzes patterns of interaction between variables of different kinds—physical, chemical, biotic, social, cultural, and economic—affecting people in relation to each other, other organisms, and their surroundings. Defined in this way, human ecology contributes significantly to the understanding of problems relating to the quality of life. It highlights the full range of human experience directly relating to the quality of life and advances understanding of the interrelationships between the elements of human experiences, including belief systems and cultural traditions, and local and global economic, technical, environmental, and societal conditions. Charles Thornthwaite referred to human ecology as an overall, integrating, and holistic field of study that may be even more all-encompassing than geography. This entry presents interpretations of human ecology from the fields of medicine, family and consumer sciences, anthropology, sociology, demography, urban analysis, geography, and biology.

The intellectual origins of human ecology lie in the emergence of plant and animal ecology in the late 19th and early 20th centuries and in the application of ecological concepts to human populations. Ecology is the scientific study of the distribution and abundance of life and the interactions between organisms and their environment. Ecologists usually either study the relationship between a particular species and the environment (such as the ecology of the rat or the bumblebee) or the characteristics of a particular ecosystem (such as the lowland tropical rain forest ecosystem). Human ecology in this sense is the study of the ecology of human beings, of their interaction with each other and with other organisms and the physical environment. Dieter Steiner and Markus Nauser argued that biology, sociology, anthropology, geography, and psychology form the five intradisciplinary “roots” of human ecology. They argued persuasively not only that human ecology should be centered in the social sciences and the humanities rather than in the natural sciences but also that it inevitably must embrace trans-scientific components of a philosophical and religious nature. Thus, in human ecology, the environment has dimensions beyond the environment of the ecosystems studies in the rest of ecology. These dimensions include culture, human attitudes and behavior, and belief systems and spirituality, as can be found in most anthropological literature concerned with human ecology.

Human ecology often focuses on how individuals and groups adapt to external circumstances, whether they are cultural, social, economic, or biophysical. The ideas and theories of human ecology should therefore be able to help increase our understanding of how groups adjust to public

Further Readings


policy actions. Adaptation in this context is the way in which a population develops or modifies social organization and technology to achieve a working relationship with its environment. Although the biological roots of human ecology would see adaptation as a selective process, analogous to the Darwinian natural selection process, human adaptation is usually discussed in terms of people making strategic choices among perceived options. However, the desirability and feasibility of some of those options are likely to be constrained by external conditions.

**Interpretations of Human Ecology**

Because the study of human life concerns everyone, it is hardly surprising that the analysis of people in relation to their surroundings has been picked up by researchers in many fields. In the 21st century, eight different interpretations of human ecology are current: in medicine, family and consumer sciences, anthropology, sociology, demography, urban analysis, geography, and biology. A ninth interpretation, not yet well formulated, is in the analysis of the human impacts of, and responses and adaptations to, global change. The nature and scale of the ecosystems studied by individual disciplines differ to some degree (Table 1).

**Medicine**

In medicine, human ecology involves studying how human beings respond in the context of the total environment, other humans, other living organisms, and physical and chemical factors such as heat, dampness, oxygen, and pollutants. This approach sees the human being as an indicator of all aspects of the quality of life. In this sense, human ecology is concerned with the evolution, organization, and interrelationships of the multiplicity of forces that shape continuing human development in a given milieu. Human ecology thus has direct relevance to medicine, for a person’s milieu influences her or his state of health, the types of maladies to which he or she is susceptible, her or his attitudes toward and use of medical care, her or his response to treatment, and her or his desire to regain her or his competitive spirit. Since an individual is an active participant in her or his social order and helps shape her or his way of life, her or his total ecology is reflected in the character of her or his physical and psychological responses.

**Family and Consumer Sciences**

In family and consumer sciences and related fields, human ecology has come to mean the study of the care and management of, the immediate, mainly indoor, ecosystems in which people live. The label human ecology is used in higher education to name many schools and faculties where nutrition, food science, clothing, and even household design are taught.

**Anthropology**

In anthropology, there is a distinct tradition of studying the close relationship of human societies to their immediate surroundings. In this case, the task of human ecology is to analyze how people are intimately interconnected to their environment in every aspect of their lives and how the people-environment system works and is sustained for future generations.

**Sociology**

In sociology, human ecology is a macrosociological analytical effort to understand the interconnections between variations in population, organization, environment, and technology in the context of communities and regions. For some sociologists, this is closely related to the urban analysis approach; for others, it is closely related to the anthropological analysis of communities.

**Demography**

In demography, human ecology has provided a paradigm that, despite a few problems, helps in understanding how populations grow and spread spatially within, and adapt to, both natural and social environments. In this way, modern human ecology has enhanced the theoretical foundations of macrolevel demography. It has also assisted in many ways in the comprehension of specific demographic issues, for example, population growth, migration, urban expansion, and cultural and ethnic differentiation.
<table>
<thead>
<tr>
<th>Discipline</th>
<th>Scale of Ecosystem Studied</th>
<th>Nature of Questions Asked About the Ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine, public health</td>
<td>The environment as it affects the individual</td>
<td>Conditions that affect the human body, both its physical and its mental well-being; internal and external environments at home and the workplace; nutrition; pollutants, disease vector habitats, and the possibility of infection and contagion</td>
</tr>
<tr>
<td>Family and consumer sciences (domestic science)</td>
<td>Conditions in the household; the environment of the family unit</td>
<td>Nutrition, living conditions, clothing, household cleanliness, exercise, and recreation</td>
</tr>
<tr>
<td>Anthropology</td>
<td>Communities in relation to the immediate surroundings on which they are highly dependent</td>
<td>The environment as a provider of the necessities of life; human skill in modifying the environment to sustain that life</td>
</tr>
<tr>
<td>Sociology</td>
<td>Groups of people in relation to their living and working environments</td>
<td>How the environment affects life opportunities; the ability to improve quality of life, including recreation and interaction with others</td>
</tr>
<tr>
<td>Urban analysis</td>
<td>Study of subdivisions of urban areas, usually at the ward or enumeration district level, in terms of various social indicators, including income, type of employment, and ethnicity</td>
<td>Indicators such as type of housing, number of persons per room, availability of piped water and sanitation, pollution, and access to facilities such as parks, schools, and hospitals</td>
</tr>
<tr>
<td>Geography</td>
<td>Usually communities in relation to specific ecosystems, such as wet rice cultivation agro-ecosystems or beachside coastal retirement communities</td>
<td>Environmental constraints on the achievement of human goals; response of the environment to human adaptations to constraints and efforts to overcome them</td>
</tr>
<tr>
<td>Biology (ecosystem dynamics)</td>
<td>Analysis of whole cities or agricultural regions</td>
<td>The turnover of energy, water, and materials through both natural and people-driven processes (related to urban and industrial ecology)</td>
</tr>
<tr>
<td>Demography</td>
<td>Large numbers of people in whole cities, provinces, or countries in relation to factors that give rise to population movements, including environmental refugees</td>
<td>Impacts of the environmental conditions on human opportunities, including factors that both attract and repel migrants</td>
</tr>
<tr>
<td>Global change science</td>
<td>How people, from individuals to whole nations, respond to global-scale changes, particularly climate change and biodiversity loss, by changing policies and behavior, particularly consumption</td>
<td>Establishing the consequences of global change for human life and for biodiversity; demonstrating opportunities for changing behavior and the importance of modifying policies to avoid the adverse consequence of further ecosystem change</td>
</tr>
</tbody>
</table>

Table 1  The scale and nature of the ecosystems studied in human ecology as applied by various disciplines

Source: Author.
Urban Analysis

In urban analysis, human ecology is the analysis of the social character of different areas of cities as a function of the demographic and environmental characteristics of those areas. This approach had its origins in the work of Robert Park and Ernest Burgess, Roderick McKenzie, and other scholars at the University of Chicago in the 1920s and 1930s. It was in part replaced by the body of theory and research that began with the publication of Amos H. Hawley’s *Human Ecology*, a landmark volume that led to a major reorientation of the field. Hawley’s work dramatically shifted the focus from the description of the physical features of a city and the mapping of social phenomena to the ways in which human populations organize to maintain themselves in given environments, thus relegating spatial analysis to a minor though still valuable position in the field. It is not spatial arrangements themselves but rather the social relations often reflected in spatial patterns and processes that are of interest to human ecologists.

In terms of biological ecosystem analysis, human ecology uses the notion of urban or agro-ecosystems. It not only analyzes the flows of energy, water, and materials affecting the urban population but also considers human behavior and attitudes in the operation of that system. This approach is exemplified by the work of Stephen Boyden and others in Hong Kong.

Geography

Much has been written about geography as human ecology, as the key study of the interrelationships between people and their environment. The roots of this interest go back to the early days of the discipline, when scholars such as Paul Vidal de la Blache and Herbert Fleure used the new concepts of evolution and natural selection in their analyses of the relationship between people and the landscapes in which they lived. At this time, there was a close relationship between geography and anthropology, and almost all geographers acquired at least a year’s intensive training in the basics of geology. A sense of both time and culture was necessary for them. These early geographers used the term “region” as their ecosystem, writing about life and landscape in the Weald in England, the Pays de Brie in France, or the Ozarks in the United States. A debate developed about the sizes, scales, and hierarchies of regions and about how human administrative areas might usefully be related to ecological units, bioregions, “natural regions,” or river basins. A later development saw the emergence of landscape ecology, a term first coined by Carl Troll in Germany in 1939. He brought the human artifacts and the cultural, social, and economic dimensions of mountain landscapes together with the biophysical factors, using highly effective profile and three-dimensional diagrams.

For some geographers, during the 20th century human ecology conjured up images of small-scale, non-Western societies and their local adaptation to the environment—typically largely self-sufficient nonindustrial communities. The work of the Berkeley School under Carl Sauer, particularly in Latin America, and that of Harold Brookfield and his students in New Guinea typified this approach. It implied a holistic view of culture and the environment and the need to be able to analyze both the nuances of culture and society and the constraints imposed on them by all the elements of the landscape. In some ways, this human ecological approach within geography helped overcome some of the disadvantages of the “top-down,” “one-size-fits-all” solutions being advocated by agricultural advisers and soil conservationists in their efforts to reduce the land degradation they believed they saw in many tropical areas.

In the 1970s, the human ecological view in geography was seen as a contrast to the spatial analysis approach, which endeavored to seek general laws about causes and effects. This contrast was explained in the United States as two distinct patterns of thought: (1) the spatial analysis, an optimizing view, stemming from research at Northwestern University, and (2) the human ecological view practiced at the University of California under the leadership of Carl Sauer. In much of Europe, the human ecological view held sway, particularly in Denmark and Germany. Later, the total human ecosystem approach was developed for the analysis of cultural landscapes, where human-environment interaction created ecological, socioeconomic, and cultural patterns and feedback mechanisms that changed biological and cultural diversity and affected ecosystem
resilience. Such concerns would be seen by many as a major focus of human ecology.

However, the great expansion of environmental concern since 1970 saw a somewhat belated return to a form of human ecological approach in geography with the appearance of what was, somewhat strangely, called environmental geography (strange because geography has always been about people and their environment).

Biology

The environmental movement also prompted the growth of human ecology out of environmental biology as science faculties rushed to set up environmental science programs. In some cases, this led to the establishment of new university programs in human ecology. The landscape architect Ian McHarg argued that human ecology should be part of planning education, since human ecology is the study of the interactions of organisms (including humans) and the environment (including humans among other organisms).

By the later 1980s, science had become worried about global change, especially the impact of climate change on human life and on the ecosystems that support life. William Clark has stressed the importance of human behavior in responding to change, particularly the need to motivate and sustain and maintain collective behavior changes. He said that the time was ripe for international, interdisciplinary commitments to scholarship on the human ecology of global change. Subsequent work by international organizations and consortia has taken a far more holistic and transdisciplinary approach than previous studies. This work has addressed fundamental geographical questions such as the relationship between climate and society or between land use and land cover change. Equally, it can be said that much of it fits comfortably under the large umbrella of human ecology.

Geography as Human Ecology?

The subject matter of human ecology and geography is essentially similar: what happens at the Earth’s surface, especially in terms of how people interact with each other and their surroundings. Geography, however, is largely content to divide this field into subdisciplines, not merely the two areas of physical and human geography but further subdividing these categories into geomorphology, biogeography, cultural geography, historical geography, urban geography, and so on. Human ecology insists on maintaining a holistic approach, although sometimes focusing on particular issues in detail, such as the human ecology of inshore fisheries or of shifting cultivation. If human ecology offers a viewpoint that geography has neglected and also contributes to other disciplines, then its holism and its emphasis on the role of the individual, and of ideas, spirituality, beliefs, and culture, can contribute to both scholarship and human well-being.

Ian Douglas

See also Berkeley School; Chicago School; Cultural Ecology; Darwinism and Geography; Energy and Human Ecology; Feminist Political Ecology; Industrial Ecology; Landscape Ecology; Political Ecology; Regional Geography; Sauer, Carl; Urban Ecology; Urban Metabolism

Further Readings

In W. L. Thomas Jr. (Ed.), Man’s role in changing
HUMAN GEOGRAPHY, HISTORY OF

Human geography has a long and complex history stretching into prehistory. At times, the evolution of human geography was closely intertwined with that of cartography and physical and environmental geography, each of which also has its own, distinct history. Every society creates its own geography, both in the sense of an ontology—that is, as material landscapes and spatial distributions—and in the sense of an epistemology—that is, as a worldview of the earth, the meaning of near and far, and how space and place reflect and affect identities. As long as there have been people, there have been human geographies. Australian Aborigines, for example, used so-called song lines to navigate the desert. The Sumerians developed clay maps of their cities, and the Polynesians crossed the Pacific Ocean with maps of currents and winds made from sticks.

Because the history of human geography has been described in detail elsewhere, this entry offers only a brief sketch of several major people, events, and schools of thought from about the 6th century BC to the beginning of the 21st century. The focus here is on Western human geography as it formed in Europe and North America; there is clearly an equally long, complex, and interesting history of geography in Asia and elsewhere waiting to be written. Note that this entry hardly does justice to the complexity of the field and that the encyclopedia includes separate entries on the histories of cartography, physical geography, and geographic information systems.

Premodern Geographies

Generally, premodern geographies were empirical and inductive in nature, often consisting of encyclopedic compilations of place descriptions, a tradition that lasted well into the 19th century. Geography was a practical science intertwined with geodesy, astronomy, surveying, exploration, trade, and military conquest.

The roots of human geography extend at least as far as classical Greece in the 6th century BC, if not before. Classical Greece, from which Western culture ostensibly arose (but with numerous connections to older cultures such as that of the Egyptians), marked the first systematic attempts to describe the shape of the Earth and map the known world, the ecumene. For example, Thales (611–547 BC), who lived in Miletus, theorized that the earth floated on water and successfully predicted an eclipse on May 28, 585 BC. Anaximander (610–546 BC) constructed what may be the first map of the world (since lost), invented the gnomon (similar to the sundial), and argued the Earth and all bodies were spherical. Herodotus (485–425 BC) was a historian who coupled history with geography in his famous studies of the Nile River, including its seasonal flooding and soil deposition along its delta. During the Athenian golden age, Aristotle (384–322 BC), a student of Plato and a scientist and philosopher in his own right, theorized a geocentric astronomical system that held sway until the 17th century. He also advocated an early form of climatic determinism based on three belts of temperature and their ability to sustain civilization: that to the south of Greece was too hot, that to the north too cold, leaving Greece alone ideal for civilization. Such a view reflects the close relationship between geography and cosmography that existed until the Enlightenment. At the famous library of Alexandria, center of the classical world’s intellectual life but since destroyed, Eratosthenes (276–194 BC) coined the term geography and estimated the circumference of the Earth remarkably accurately. Later, Hipparchus (190–120 BC) theorized a grid of the world consisting of latitude and longitude lines.

Within the Roman Empire, prominent geographers included Strabo (64 BC–AD 24), who, like many intellectuals of the age, was actually Greek; he is best known for his 17-volume work Geography. Ptolemy (AD 87–150), also working in
Alexandria, concluded that the task of geography is the description of the earth as a whole and presented such a description in his eight-volume *Guide to Geography*. He differentiated geography as the study of universals from topography as the study of localities and chorography as integrating the two. His worldview dominated the Western geographical imagination for a millennium, until the “voyages of discovery” of incipient capitalism dethroned it, influencing explorers such as Columbus.

For a millennium under feudal Europe, geography suffered from the political and ideological dominance of theology; indeed, the rationalist Greek tradition was effectively ended by the hegemony of Christianity. Exploration during this time was relatively rare, largely limited to the Normans, the Vikings, and the famous trips to Asia by Marco Polo, whose views also affected later, Renaissance explorers. A well-known medieval geographic expression consisted of T-in-O maps, oriented to the east (i.e., Jerusalem, which was put at the center), which depicted the continents of Europe, Africa, and Asia in crude, highly inaccurate terms that served ideological purposes more than anything else.

In contrast, during the height of the Arab Empire from the 7th to the 12th centuries, geography prospered, in much the same way as did Arabic mathematics (e.g., algebra), astronomy, poetry, and medicine. The Arabs traded extensively with India and discovered the dynamics of the monsoons over the Indian Ocean. Arab cartography was so advanced that Christian kings such as Norman Roger II in Sicily hired Arab mapmakers such as al-Idrisi (1099–1180). In the 9th century, Caliph Harun al-Rashid assembled scholars to translate Greek works to Arabic. Prominent Arab adventurers included Ibn Batuta (1304–1369), who traveled more than 70,000 miles throughout Eurasia over 30 yrs. (years). Abu Al-Raihan al Biruni (972–1050), a Persian born near the Aral Sea, wrote the *Kitab al-Hind*, which first examined the erosion of the Himalaya mountains. Ibn Khaldun (1332–1406), scholar for the sultan of Egypt, wrote a multivolume world history, the *Muqaddimah*, which explicitly included human-environment interactions (possibly the world’s first).

### The Renaissance and the Enlightenment

The gradual expansion of capitalism throughout the 16th to the 19th centuries provided an enormous stimulus to geography, which was highly useful in charting avenues of exploration and conquest, mapping land uses and the distributions of resources across the planet, and helping Europeans understand the worlds they were conquering. Thus, the Portuguese king Henry the Navigator sponsored a series of voyages down the west coast of Africa, including Bartolomeu Dias’s trip around the Cape of Good Hope in 1488 and Vasco da Gama’s trip to India in 1497. Magellan set out to sail around the world but died en route (one of his ships completed the voyage). Columbus, sailing for the Spanish Crown, inadvertently discovered the Americas in 1492, opening a vast new chapter in the rise of the West. Scientific voyagers included Captain James Cook, who undertook three voyages throughout the Pacific in the 18th century. Explorers and scientists brought back vast quantities of data and plant, animal, and mineral samples to Europe, much of it organized, stored, and displayed in universities, museums, zoos, and botanical gardens.

During this era, cartography exploded in scope and sophistication. Many of the first maps produced then were nautical sea charts, including portolan charts of coastal areas. In the 1400s, Martin Behaim in Nuremberg created the first globe. Cadastral maps for surveying and establishing the boundaries of property became common. During the Dutch golden age, when Amsterdam was a major commercial center, the first atlases appeared; these were so important that they were often national secrets. In the 16th century, Martin Waldeemüller (1470–1522) made the first map that showed the Americas, immortalizing the name of the new continent. Gerardus Mercator (1512–1594), a Flemish engraver, created a famous projection in 1569 that allowed the use of straight rhumb lines, or lines of constant compass bearing, which was highly useful for long-distance navigation; the Mercator projection became the world’s most commonly used for centuries to come.

The Enlightenment also saw several prominent geographers make a break with theology. Bernhard Varens (Varenius) was a 17th-century
German who wrote the *Geographia Generalis* in 1650, which served as a major textbook for the next 150 yrs. and was translated into English by Isaac Newton. He distinguished between *specific geography*, which was concerned with the unique character of places, and *general geography*, which was concerned with universal explanatory laws rather than simply collecting empirical data.

Immanuel Kant (1724–1804), better known as a philosopher, was also a professor of geography at the University of Konigsberg for 40 yrs. (1756–1797). Kant made numerous contributions to geography, although his factual assertions about other cultures were often empirically erroneous and racist. His philosophical orientation attempted to resolve the debate between British empiricists and Continental rationalists, arguing that the mind is predisposed to the rational organization of sense data. Kant maintained that people never experience things in themselves (*noumena*), only their sense impressions of them (*phenomena*). The world thus has no inherent, preexisting order but is constructed by the mind. Time and space are categories created by the mind to make sense of nature; they are not phenomena themselves but ways to organize phenomena. Kant's contributions to geography included papers in physical geography and his advocacy of a view of absolute space as an abstraction separate from nature. Importantly, he held that space was on a par with time in explanation, a notion that would be smothered by the rise of historicism in the 19th century. Kant held that geography, like history, was concerned with the study of empirical phenomena, and he differentiated between “mathematical geography” (maps and surveying), physical geography, political geography, moral geography (essentially, cultural geography), commercial geography (trade), and theological geography (religious views of landscapes).

**European Human Geography in the 19th Century**

The Industrial Revolution, urbanization, the growth of literacy, expanding universities, and the growing pragmatic need for geographic information in the face of colonialism gave rise to a steady growth of geographic knowledge and the professionalization of the discipline. A primary manifestation of this trend was the founding of national geographical societies in Europe, such as the French *Société de Géographie* in 1821; the German *Deutsche Gesellschaft für Geographie* in 1828; the Geographical Society of London (later the British Royal Geographical Society) in 1830, which later became the Institute of British Geographers in 1934; the *Russkoe Geograficheskoe Obshchestvo*, or Russian Geographical Society, in 1845; the *Società Geografica Italiana*, or Italian Geographic Society, in 1867; the Royal Dutch Geographical Society in 1873; and the *Svenska Sällskapet för Antropologi och Geografi*, or Swedish Society for Anthropology and Geography, in 1877. Such societies, along with many other small organizations, led to a proliferation of conferences, sponsored talks, and journals that reflected and contributed to the exponential increases in geographical knowledge throughout the period. Many also served to legitimate the brutal colonial conquests of other parts of the world then under way.

The two leading geographic figures during this period were Alexander von Humboldt, one of the 19th century’s most important scientists, and Carl Ritter (1779–1859). von Humboldt is best known for his extensive travels in Latin America (1799–1804) and Siberia (1837–1842). He accumulated vast amounts of empirical data on plants, volcanoes, and climate, among others; he was the first European to see the Orinoco River in Venezuela, and he discovered the Humboldt Current; he was the first to use isolines, such as isobars and isotherms; he theorized the notion of continentality, in which climates far from the ocean behave differently from those nearby; he discovered that air temperatures decrease with altitude and he conducted extensive studies on South American tribes. Many of his observations are contained in his five-volume work *Cosmos* (1830–1859), which offered an agnostic, holistic view of nature, arguing that Earth must be viewed as a unified organic whole. His views influenced, among others, Simon Bolivar and Thomas Jefferson.

In contrast, Carl Ritter (1779–1859) taught geography at Frankfurt and Berlin, traveling some in Europe but not beyond. He is best known for his massive 19-volume work *Erdkunde*, which emphasized the comparison and synthesis of regions as an expression of a religious teleology.
Humboldt and Ritter are often considered the founders of modern geography; however, whereas Humboldt was secular, Ritter was religious; Humboldt focused on the physical environment, Ritter on human geographies; Humboldt worked at a fine level of areal differentiation, Ritter worked at the scale of continents.

The 19th century is also known for two famous anarchist geographers. Éliseé Reclus (1830–1905) participated in the Paris Commune in 1871 and was subsequently imprisoned and banished. In his 19-volume Nouvelle Geographie Universelle and 6-volume L’Homme et la Terre, he exhibited a concern with social inequality, preservation of the environment, and town planning. Peter Kropotkin (1842–1921) was a Russian aristocrat who became an anarchist after serving as a military officer in Siberia; in 1885 he wrote the essay “What Geography Ought to Be” in prison, arguing that spatial hierarchies mirror and reinforce social ones. His philosophy emphasized “mutual aid” among decentralized self-governing communities.

The Development of North American Geography

From its inception, the United States developed its own tradition of geographical thought and practice. In addition to his many other accomplishments, President Thomas Jefferson was greatly interested in geography. He negotiated the Louisiana Purchase, sponsored the Lewis and Clark expedition, and initiated the township and range system of land ordnance in 1785, which helped bring the territories of the expanding Western United States into a rationalized, Enlightenment frame of consciousness. The late 18th century also witnessed vast numbers of atlases, textbooks, gazetteers, and travel guides. Jedediah Morse (1761–1826), a Connecticut Calvinist preacher, often called the father of American geography, wrote several bestsellers to assist Americans in understanding their own territory, including the Native Americans; his efforts formed a vital part of the construction of American identity in the early phases of its nationhood.

Human geography in the United States was slow to develop, in part due to the domination of the field by physical geographers such as William Morris Davis (1850–1934). American human geography also exhibited several characteristics that differentiated it from its European counterpart. There were strong links between American geography and the ongoing colonization of the West: Geographers were active in the so-called opening up of the West through their surveys, charts, maps, and photographs throughout the 19th century, transforming what was for Europeans and Euro-Americans a blank space into a mappable, knowable, and hence controllable one. Human geographers in the United States placed great emphasis on induction (in contrast to European theorizing), fieldwork, and applied, pragmatic applications, and they suffered from suffocating empiricism long after their French, German, and British counterparts had begun to move into more theoretically sophisticated perspectives.

In the latter part of the 19th century, geography became progressively institutionalized as a discipline in professional societies and universities. The American Geographical Society, formed in New York in 1851, sponsored expeditions and the nation’s oldest geography journal, the Geographical Review. In 1888, the National Geographic Society began in Washington, D.C., to serve scientists working for the federal government. Under its energetic editor Gilbert Grovesner, the society’s official journal, National Geographic, grew rapidly in popularity and subscriptions, helping to bring the geographical imagination of American foreign conquests home to the expanding middle class. In the process, it became the unofficial voice of American foreign policy. By the 1920s, with more than 1 million subscribers to its journal, the National Geographic Society was the largest educational society in the world, and its photos and texts exercised considerable influence over popular conceptions of geography.

Geographical studies were prevalent throughout the Ivy League in the early 20th century. The first department, however, was at the University of California, Berkeley, which began in 1897. The first PhD program was located at the University of Chicago; founded in 1903, it produced a long stream of famous graduates, including J. Paul Goode, Harlan Barrows, Gilbert White, Homer Hoyt, Derwent Whittlesey, Carl Sauer, and Richard Hartshorne. In 1904, the founding of the Association of American Geographers in Philadelphia, with William Morris Davis as its
first president, marked the growing professionalization of the field; the largest national geographic organization in the world today (with more than 10,000 members), it publishes the *Annals of the Association of American Geographers* and *The Professional Geographer*. Somewhat later, in 1951, the Canadian Association of Geographers held its first meeting.

**Geopolitics and Environmental Determinism**

As opposed to encyclopedic empiricism, in the late 19th century, classical geopolitics and environmental determinism arose as geography’s first true paradigm, marking a shift in the discipline from a collection of facts to a body of theory. This move was closely associated with the aftermath of the Darwinian revolution and the secular challenge to Christian dogma, although it also drew on the earlier (and erroneous) ideas of the French biologist Jean Baptiste Lamarck (1744–1829). The incorporation of the Lamarckian variant of Darwinism centered on the notion that culture is carried biologically, which removed the random chance central to Darwinian theory and posited evolution in much more rapid terms than did natural selection. Social Darwinism came to privilege the biological over the social in the explanation of history and geographies, often legitimating inequality as natural and necessary, as in the works of the historian Herbert Spencer. Not coincidentally, this view of competition and hierarchy occurred amid the waves of European colonialism.

*Classical geopolitics*, a term coined by the Swedish political scientist Rudolf Kjellen, was formalized in the works of Friedrich Ratzel (1844–1904), who gave formal expression to German fears of encirclement at the hands of Russia, France, and Britain. Sometimes called the father of human geography, Ratzel maintained in his *Anthropogeographie* that nation-states could be viewed as organic, biological organisms. If they were not growing, then they were dying. In their search for living space, or *lebensraum*, states would inevitably come into conflict, or *kulturkampf*. Ratzel’s views thus biologized international relations, making them appear as natural rather than social creations, and were read eagerly by later German leaders, including Adolf Hitler. The Nazi geographer Karl Haushofer (1869–1946) was instrumental in this regard.

The paragon of classical geopolitics was Sir Halford Mackinder (1861–1947), who taught at Oxford University and served as a member of Parliament. In *The Geographical Pivot of History*, written in 1904, he was one of the first theorists to conceive of the globe as an integrated political system. His argument centered on the notion that the age of sea power was over and that railroads, in opening up the interiors of continents, were generating new geographies of centrality and peripherality. The heartland, in this reading, consisted of Eastern Europe and Western Russia, a pivot area relatively inaccessible to marine powers.

As the first ostensibly scientific paradigm in geography, environmental determinism framed the world in terms of a hierarchy of competing races in which climate, continents, and ethnic groups were flattened to dichotomies such as civilized versus uncivilized. Geography textbooks often described dark-skinned peoples as indolent and lazy, in need of Western intervention. Ellen Churchill Semple (1863–1932), a student of Ratzel’s, was a prime proponent of this view, arguing in books such as *The Influences of Geographical Environment*, published in 1911, that climate and topography exerted essentially uncontrollable influences over people. Ellsworth Huntington (1876–1947) and Griffith Taylor (1880–1963) wrote in much the same vein, a line of thought that culminated in the racist program of eugenics.

By World War I, environmental determinism was increasingly falling into disfavor under the withering attacks of cultural geographers such as Paul Vidal de la Blache in France and Carl Sauer in the United States. Its principal errors included its omission of countervailing facts and its selective use of evidence, its inability to account for social relations and culture and thus the variable responses to environmental constraints, its ridiculous and unscientific racism, and its simplistic understanding of nature, which itself has been heavily modified by people. The alternative doctrine of environmental possibilism, which gave much more weight to the capacity of people to shape their own worlds, began to gain legitimacy. The legacy of environmental determinism, however, included a widespread retreat from
theory in general, which greatly hampered human geography’s subsequent intellectual maturity, and a bifurcation between human and physical geography that put nature off-limits to social analysis until this schism began to heal in the 1990s.

Isaiah Bowman (1878–1950) was a geographer mostly known for his prodigious administrative and political accomplishments. He studied under Davis at Harvard, taught for a decade at Yale, and participated in the American Geographical Society–sponsored expedition to Peru that revealed Machu Picchu in 1911. Later, he served as director of the American Geographical Society (1915–1935), taking time in 1919 to work with the American delegate to the Paris Peace Conference in 1919, where he played a key role in drawing the boundaries of the new post–World War I Europe. A founding member of the Council of Foreign Relations, which publishes *Foreign Affairs*, he also became well acquainted with Presidents Wilson and Franklin Roosevelt. From 1935 to 1948, he was president of Johns Hopkins University, during which time he was a delegate to the conference that led to the founding of the United Nations.

World War II also deeply affected geography, particularly in the United States. Hungry for geographic information about distant conflicts, the public turned to maps in record numbers. Numerous planners and tacticians gained experience in cartography and air photo interpretation, and the quantitative skills learned by others became important in shaping the subsequent changes in academic geography.

**Cultural Geography and Chorology**

As part of its rejection of environmental determinism in the 1920s, the discipline of geography embraced the long-standing tradition of chorology, also known as areal differentiation. In Europe, the Annales School was important in this regard; a central figure was Paul Vidal de la Blache (1845–1918), the father of French geography, well-known for his studies of small rural areas called *pays* and their associated styles of life, or *genres de vie*. Like many observers, he viewed culture and the soil as deeply shaping one another; however, unlike the environmental determinists, he refused to collapse the social into the physical. By observing how widely lifestyles varied in what was essentially a homogeneous climate, he initiated a viable alternative to environmental determinism. He also played a central role in the introduction of possibilism to the discipline, a notion first advanced by the historian Lucien Febvre. His German counterpart was Alfred Hettner (1859–1941), who argued in the Kantian tradition that geography consisted of the art of regional synthesis, seeking relations among phenomena that other disciplines ignored.

Carl Sauer (1889–1975) looms large as the father of American cultural geography. Teaching at the University of California, Berkeley for three decades (1923–1954), and giving rise to the Berkeley School, which differed greatly from the discipline’s Midwestern roots, he offered a view of culture that avoided the ugly racism pervasive in environmental determinism, advocating instead a relativist reconception that uncoupled moral superiority from military or economic might. Sauer’s accomplishments include the introduction of the concept of *landschaft* or landscape into American geography as both a cultural and a natural product; the study of cultural hearths, where innovations such as agriculture began; his advocacy of fieldwork (he was an expert on Mexico); and his insistence that cultural geography take historical context seriously. Sauer’s department generated a large number of influential cultural geographers such as John Leighly, Fred Kniffen, Joseph Spencer, Andrew Clark, James Parsons, Carville Earle, Wilbur Zelinsky, and Marvin Mikesell. At Harvard, Derwent Whittlesey (1890–1956) introduced the notion of sequent occupance, a technique for analyzing landscapes as the product of successive groups over time, each of which leaves an imprint, forming a palimpsest.

The most famous advocate of chorology was undoubtedly Richard Hartshorne (1899–1992), who studied under Alfred Hettner, before graduating from the University of Chicago in 1924. The chorologists maintained that the essence of the discipline was the description of regions in all their glorious uniqueness and complexity, including cultural and physical phenomena. Hartshorne argued that the most productive analyses focused on small, relative homogeneous regions, noting that any deployment of the regional concept was inherently a subjective tool to find meaning in the unwieldy complex of data found in the world.
Regions, thus, were mental tools to impose order on chaos. By eschewing theory, chorology found itself mired in empiricism, and the discipline’s theoretical progress was halted.

Chorology, and the empiricist cultural geography that it sustained, drew to a close in the 1950s, beginning with the famous attack on Hartshorne’s worldview by Frederick Schaefer in 1953. Essentially, Schaefer claimed that the view of geography as an integrative science concerned only with the unique was naive and arrogant, for uniqueness was a problem common to many sciences. By refusing to search for explanatory laws, geography condemned itself to what he called an “immature science.” Rather than idiographic regions, geographers should seek nomothetic regularities across regions. This critique helped open the door to the rise of positivism and the quantitative revolution.

**Positivism and the Quantitative Revolution**

Starting in the 1950s, human geographers embraced a new theoretical paradigm, logical positivism. Epistemologically, this view drew from the Vienna Circle to embrace the scientific method, quantitative methods, hypothesis testing, reproducible results, prediction, and the correspondence theory of truth, setting out to refashion human geography as a science. Drawing on older traditions such as applied geometry, physics, classical German location theory (e.g., the von Thünen model, Weberian location theory, and Christaller’s central place theory), and neoclassical economics, this school advocated a Cartesian view of space, that is, geography as geometry, in which landscapes are reduced to isotropic planes. Central to this paradigm were the surfaces, nodes, and hierarchies found in models, including central place approaches to urban systems, gravity models, diffusion models of the spread of diseases and innovations, entropy-maximizing models, location-allocation models to optimize distributions, multivariate statistics, and input-output models to simulate economic systems. Appropriate models were held to distill the essence of the world, revealing its causal properties through the act of simplification.

The originators of the quantitative revolution in geography included the faculty at the Universities of Iowa and Wisconsin, but it was the University of Washington that famously became its epicenter. There, under the guidance of William Garrison, a cohort of “space cadets” came to play an enormous role in furthering the new paradigm. Brian Berry became a giant within urban and economic geography; William Bunge’s *Theoretical Geography* sought to inject rigorous geometry into the field, although he later became radicalized. Richard Morrill wrote extensively on spatial demographics and political redistricting. Others included Duane Marble, John Nystuen, Waldo Tobler, and Michael Dacey, all of whom became leading figures in their day. In Britain, Peter Haggett and Richard Chorley played a similar role.

Although it was highly successful within its own frame of reference, the positivist school also found itself facing increasingly heavy criticism in the 1970s. Humanists objected that such an approach might work well in the natural sciences but not in the social sciences. Critics held that positivism denied the existence of an observer, offering a false sense of objectivity; even the attempt to be scientific and objective is, after all, a value. Rather, critics alleged, all data are value laden and filtered through theory, so that the fact-value distinction is untenable. Positivism’s celebration of quantitative techniques was criticized as sterile and overly restrictive; math is but one way to understand reality and not always the optimal one for the analysis of phenomena that often can only be studied through interpretive forms of understanding. Finally, Marxists argued that positivism’s ahistorical approach lacked any account of social relations, including class, power, and culture, and thus focused on empirical forms rather than deep social processes. In this reading, positivism deprived itself of any means to comprehend social change.

**Marxist Geographies**

Drawing on the extensive tradition that began with Karl Marx (1818–1883), geographers in the 1960s and 1970s constructed a view of space and landscape centered on political economy. While there are many varieties of Marxism, they share in common a concern for the centrality of class, the production process, the importance of labor, a deeply historical understanding of how societies are constructed, and the power and politics that pervade all societies, including capitalism. Marxist geographers viewed space in explicitly
social terms, that is, as a construction of historically contingent social structures and relations. The introduction of Marxism into geography was thus simultaneously the spatialization of Marxism as an analytic tradition; historical materialism became historical-geographical materialism. In the process, geography became truly social in outlook, and the understanding of how landscapes and spatial distributions were created and changed became inseparable from the analysis of how societies are structured and transformed.

David Harvey (1935–) played the major role in this process through a long series of influential books that introduced geographers to historical materialism and reworked it along geographic lines. Harvey injected into geography famous notions such as the cycle that linked commodity production to money to commodities, which lay at the heart of capitalist production. Starting with Social Justice and the City in 1973, Harvey’s works electrified the discipline, reorienting its social analysis, in which landscapes were seen as filled with power relations that perpetuated inequalities. Every social formation under capitalism, he argued, constructs what he termed a spatial fix, an optimal landscape that reflects the prerequisites of production yet simultaneously inhibits future rounds of production. Geographies are thus poised between the need for capital to generate spatialities that facilitate capital accumulation and the ever-present need to change those geographies in the perpetual search for growth and expansion. In so doing, Harvey showed that time and space are not absolutes that lie outside society but products of those societies, a move that marked a gradual transition from absolute to relative and relational space.

The contributions of other Marxist geographers such as Neil Smith, Richard Walker, and Michael Storper included shedding light on questions of uneven development and spatial divisions of labor; revealing the central role of the state in the formation and maintenance of capitalist relations (in contrast to the mythology of the free market); reworking urban theory around the issues of production, class, and social reproduction, including topics such as suburbanization, inner-city poverty, and gentrification; and adding great depth to international political economy, primarily through intersections with schools of thought such as dependency theory and world systems theory. Other Marxists initiated a tradition concerned with the social construction of nature and environmental politics, while yet others ventured into the domain of cultural geography, portraying culture and cultural landscapes not just as sets of ideas but as power relations.

Critics of the Marxist tradition often pointed to its tendency to economic determinism, that is, the reduction of all social issues to labor and production. Others argued that Marxism suffered from an inadequate theorization of human agency and human consciousness. In the late 20th century, Marxism, which had thoroughly reworked human geography, was complemented and at times contested by several other perspectives on how space and society were fused.

Humanistic Geography

In the 1970s, some geographers turned toward the philosophical traditions of phenomenology and existentialism. Originating in hermeneutics, the study of textual meanings that had medieval roots, this school drew on the works of philosophers such as Edmund Husserl (1859–1939) and Martin Heidegger (1889–1976) to explore the implications of human experience in a world without fixed meanings. Humanistic geographers such as Edward Relph were concerned to put people back at the center of social analysis, intersecting with psychology, humanistic philosophy, literary analysis, and linguistics to offer a rich portrait of what it means to be human, that is, to construct webs of symbolic meaning. Jettisoning the myth of objectivity, humanist geographers argued that understanding comes from shared interpretations and the clarification of values.

Central to the project of humanistic geographers was the work of Yi-Fu Tuan, who redefined the notion of place from a sterile, tangible object to the intangible meanings that people give to it. Place, as an embodied, erotic, and highly personal locale central to everyday life, was contrasted with space, a more abstract, Cartesian notion. Humanistic geographers focused on how consciousness constructs places through understanding and interpretation, that is, how landscapes are authored. Sense of place became a term that encapsulated this notion of locales as intangible and symbolic, in contrast to conventional cultural geography’s focus
on material landscapes. This line of thought led to the exploration of individual life-worlds and the spaces of the body, the most intimate of geographies. Bodies appear natural but are social constructions, inscribed with social meanings. In arguing for the centrality of human consciousness, humanism mounted a serious challenge to both positivism and Marxism, forcing social science to take seriously the implications of culture, ideology, everyday life, and social reproduction (e.g., in recognizing the role of contingency, the capacity of human actors to do otherwise).

Criticisms of humanism maintained that this perspective lacked a systematic account of social relations, class, power, and production. Thus, humanistic thought centered on an asocial, ahistorical, undersocialized view of the individual, without reference to the mechanisms of social reproduction. Attempts to reconcile humanism and Marxism in the 1980s led human geographers to explore lines of thought such as structuration theory.

Geography and Feminism

Geography has long been a male-dominated discipline. As female academics grew in numbers and were inspired by the women’s movement of the 1960s and 1970s, feminist geography grew in size, importance, and sophistication. While there are many views within feminism, all of them assumed the common point of departure that focused on gender. Feminists, such as Susan Hanson, Gillian Rose, and Linda McDowell, maintain that social reality is pervasively gendered and that gender relations intersect (and often precede) class, generally as manifested through patriarchy, that is, gender relations that favor men at the expense of women. Feminism as a political project seeks not to eliminate gender but to eliminate the inequality that arises from patriarchy.

Feminist geographers made numerous contributions to the field, focusing on how gender relations are intimately woven into existing allocations of resources and modes of thought in ways that generally perpetuate patriarchy. To ignore gender is to assume that men’s lives are “the norm,” that there is no fundamental difference in the ways in which men and women experience and are differentially enabled and constrained by social relations. Widely recognized as the first non-class-based form of social determination to acquire legitimacy, gender has been thoroughly denaturalized: While gender roles may appear to be natural (i.e., outside of society), they are socially constructed as webs of masculinity and femininity. Feminists opened up the family as an object of geographic scrutiny, questioning the schism between production and reproduction, the economic and the social. In urban geography, feminists focused on gender differences in commuting. Methodologically, feminism helped legitimate the use of qualitative methods such as participant observation, standpoint theory, and grounded theory, emphasizing that knowledge always is a view from somewhere and context-bound.

Postmodernism and Poststructuralism

The 1980s and 1990s witnessed rising diversity in how geographers came to view the world, including the recognition that modernity, far from being a universal feature of human life, was one historical project among many. Diverse thinkers coagulated into a school of thought that came to be known as postmodernism and in the 1990s as the more politically assertive poststructuralism.

It is critical to note that there are many variations in this line of thought, but commonalities typically include placing great emphasis on the constitutive role of language and ideology in the formation of social life. Like humanists, postmodernists argue that every discourse interprets the world from a particular vantage point, that every view is a view from somewhere, and that what one sees depends on where one stands. Postmodernists maintain that for every topic, there are inevitably many competing discourses, none of which is inherently more correct than others. There are thus no a priori grounds for deciding what is true or not. To the postmodernist, everything is a discourse because there is no way to see the world outside of discourse. Such a view intersected with the literary tradition of deconstruction, in which texts are pulled apart for their diverse, often contradictory meanings. It also borrowed heavily from the works of Michel Foucault (1926–1984), who emphasized that all knowledge is inescapably sutured to power: Discourses were not simply reflective of the world but constitutive of its inhabitants. From this view, all grand sweeping views of
reality (often labeled *metanarratives*) sweep a great deal under the carpet, obscuring as much as they reveal. Indeed, the essence of postmodernism is that reality is more complex than our languages allow us to admit and that every linguistic construction of order is a simplification and distortion. Thus, every representation of reality, every discourse, is inescapably political; there can be no divorce between the ontology and epistemology of viewpoints.

Postmodern geographers are a diverse group. Marxists, such as Edward Soja and David Harvey, argue that postmodernism is the latest cultural expression of advanced capitalism and that so-called postmodern landscapes reflect the emergence of a globalized, hypermobile, post-Keynesian, post-Fordist regime of production. In this view, postmodernism is essentially a response to the enormous wave of time-space compression unleashed by contemporary capitalism. Others employed the postmodern celebration of difference to reassert the significance of localities and local uniqueness, arguing that when and where social events happen is fundamental to how they happen, a move that elevates geography to the level of epistemology.

Postmodernism gradually gave way to a more politically assertive poststructuralism, although the two terms overlap considerably and some authors use them interchangeably. Like feminism, postmodernism welcomed views from subjugated minorities, the suppressed Other, the subaltern in the developing world. Instead, the poststructuralists ask, who is it that gets to decide what constitutes valid, legitimate, correct, or proper discourse? As an emancipatory political project, this view forced a philosophical shift from the social core to its periphery, from the center to the margins; that is, it required intellectuals to recognize the importance of gender and race, not only ontologically (i.e., as parts of social reality) but also epistemologically (i.e., as they pertain to the creation of knowledge).

Critics of postmodernism accuse it of degenerating into intellectual nihilism and endless relativism, in which all positions come to have equal weight. Some Marxists argue that the postmodern focus on culture and discourse has submerged class as a meaningful social category. Moreover, an overemphasis on difference can be politically disempower-

ing, for without a common political project resting on common assumptions and values, it is difficult to forge alliances across a diverse social spectrum.

More recent issues in human geography have forged even more adventurous conceptions. Drawing on the works of Bruno Latour, for example, poststructuralists have pursued actor-network theory to jettison long-standing dichotomies (e.g., individual and society, culture and economy, nature and culture, time and space), even that between human and nonhuman actors, to create novel notions of hybridity. Rather than places, poststructuralist geographers emphasize mobilities, connectivities, flows, rhizomes, and networks in a relational ontology of space, one that views geographies as always coming into being and forever under construction. Like Doreen Massey’s power-geometries and work on commodity chains, this line of thought emphasizes geography as a series of interconnected relational places rather than discrete locales, produced by and in turn shaping social relations in a continuously intertwined mixing. Some use this approach to examine the social production of scale, and others even call for eliminating scale as an analytical category.

**Conclusion**

This brief review has done little more than sketch some of the broad contours of how human geography as a discipline has existed and changed over two millennia. The field has long served society—typically its hegemonic interests—in numerous ways, including exploration and trade, naturalizing colonialism and racism, and urban and regional planning efforts; more recently, given the hegemony of political economy and social theory, human geography has exhibited a sustained interest in exposing and challenging social and spatial inequalities, denaturalizing what appears given and pointing toward more socially just visions of the future. Given the diversity of topics and approaches, it is clear that there is no single way to view human geography but a plethora of contending schools of thought about space that intersect in creative ways. Moreover, human geography’s history is unfinished, for new ways of looking at space are always emerging and are ever likely to do so.

*Barney Warf*
An invasion of a species is defined as the introduction, establishment, and subsequent spread of that species in a geographic area different from its original or native geographical range. Once a species has been introduced into a new habitat, it can be naturalized; that is, it can adapt to the new environment and expand its population, usually producing negative effects on native species and on the whole ecosystem structure. Not all human-induced introductions of species are successful, and invasive populations can become extinct shortly or even after a long time. There are two aspects to consider in the ecological study of invasions: (1) the susceptibility of a territory to an alien invasion (i.e., the suitability of a territory to the ecological requirements of an invasive species and its proclivity to be invaded) and (2) the invasiveness of the species (i.e., its capacity to become an invader), which depends on its ethological, physiological, and morphological characteristics, as well as on the number and frequency of invasions on the same habitat over time. This entry
discusses how an invasion occurs, the effects of invasive species on ecosystems, the history of invasions on islands and elsewhere, and future efforts to control invasive species.

The invasive capacity of plant species will be determined primarily by its capacity for dispersal and spread, rapid growth, great height (increasing its access to light), high leaf area, high use efficiency of the available resources, and great tolerance to environmental stress. Invasive animal species tend to have more flexibility in behavior (including partnership with humans), more aggressiveness, higher reproductive rates, and broader ecological niches (more generalist species).

With regard to habitats, disturbed and highly isolated ecosystems are prone to be invaded. They support communities structured in simplified networks. New invasive species modify the ecological relationships in the networks, even affecting the whole ecosystem when aliens are recruited among top predators or herbivores.

**How Does an Invasion Occur?**

Humans, due to their unique ability to remove natural barriers, are responsible for many species colonizing geographical areas located far away from their original habitat through different pathways, which in some ways have changed over history. Briefly, introductions may be as follows:

*Intentional.* When humans move from one place to another, they intentionally introduce a different species for its use in terms of agriculture, livestock, hunting, fishing, or gardening.
**Involuntary.** Human activities, especially in modern and contemporaneous times, have promoted the introduction and spread of species from very distant regions and between both hemispheres. Unintentional invasions of species have been favored by ballast water exchange, species traveling attached to the hull of ships, escapes from farms and gardens, species traveling along with agricultural products or transport vehicles, species used in biological control of plagues, or artificial connections of different watersheds. Not only are human-introduced species considered potential invasive organisms, but also the parasites of these invasive species can cause extremely negative effects on native species.

Apart from the direct introduction of plant and animal species, humans have an important indirect role in the passive invasion of species related to the putative human-induced climatic change. Despite the arduous discussion about the origins and effects of the global climate change, different species are being induced by the global temperature warming to move to new locations.

**Effects of Invasive Species on Ecosystems**

Although invasion biology emerged as a discipline devoted to the study of a primordial topic related to the current biodiversity crisis, its most abundant and robust documentation comes from insular vertebrate paleontology. Recent studies on current ecosystems allow an accurate understanding of the invasion mechanisms, but it should be noted that major invasive processes took place in past times. The recorded global loss of biodiversity in birds and mammals that occurred following the human colonization of islands involved ca. 3,000 species of birds and ca. 200 species of mammals. This extinction event occurred mainly in prehistoric times, and it is one of the global effects of invasive species. Many extinction processes occurred also on continents following the human spread. Although there is still debate on their original causes, climate-related hypotheses are being frequently excluded, while human spread of invasive species, and its consequences on ecosystems, appears as a more plausible hypothesis to explain them.

Even currently, the effects of invasive species on native communities/ecosystems can acquire dramatic dimensions for nature, not only ecologically but also economically (when invasion becomes a plague, directly affecting human interests). Mostly, invasive species act as predators and competitors and have a direct impact on native species. In many cases, the autochthonous species have evolved without predators or competitors so that they do not display defense mechanisms against the new settlers. The impact of the new species can lead the native species to extinction, especially at low population densities.

Eventually, the invasion of a species results in the hybridization and genetic contamination of a native species if there is a genetic exchange between the new and the autochthonous species. Other important effects can be produced indirectly by the introduction of parasites and pathogens that can attack native species, which often lack an immune defense against them.

The interferences with the ecological networks and relationships among native species (such as mutualism) by an invasive species have been also accurately studied. The elimination of mutualisms can promote not only the extinction of one species but also the extirpation of a cascade of species involved in an ecological network.

As a result of all these effects, invasive species decrease biodiversity on the global level, although their effects on particular ecosystems, especially on islands, can sometimes increase local biodiversity.

**Past Invasions on Islands**

The human diaspora colonized the islands of the world through a process that started in the Paleolithic and ended in roughly the 15th century with the settlement of the Pacific Ocean islands. Together with humans, a plethora of invasive species spread on islands’ ecosystems, resulting in drastic changes in the island networks, including both the extinction of natives and the remodeling of island ecosystems. Although the main changes usually occurred just after the first colonization event, some major changes have been recorded in later periods.

Everywhere, human arrival involved the spread of domestcants, commensals, and opportunistic invasive species. The invasive species associated
with each colonization depended on the cultural background of the source communities. Thus, as examples, typically the prehistoric colonization of the Mediterranean islands involved goat, sheep, cow, pig, dogs, and the formerly commensal wood mouse and garden dormouse. The later Roman spread, after the Punic wars, involved a new wave of invasions, including those of black rat, house mouse, chicken, horse, donkey, and other species. On the Pacific Islands, the prehistoric Lapita colonization involved the spread of dogs, pigs, chicken, and kiore. On the Canary Islands, the prehistoric colonization involved the arrival of the house mouse, goat, sheep, pig, and probably the dog. In all these examples, each invasion wave was coeval with an extinction event, suggesting a close relation between them. Also, everywhere, the opening of forests for agricultural purposes through the use of fire contributed to the dispersal and spread of opportunistic invasive (and sometimes native) plant species, which colonized the new space free of competitors.

The presence of a reduced number of mammalian species displaying atypical features acquired in the process of their evolution under isolation conditions is a characteristic of the true islands relatively close to the mainland. The introduction of invasive species with their pathogens is related to the extinction of native species of mammals. Not all alien species have had the same effect on the invaded ecosystems, with the introduced opportunistic predators the top modifiers of ecosystems. On most islands, before human arrival, there were no predators, except for some birds. The introduction of carnivore species by humans (e.g., dogs, cats, weasels, mongooses, snakes, etc.) has been responsible for the extinction of native wildlife. A well-known and documented case is the introduction of the weasel (*Mustela nivalis*) by the Romans on the islands of Mallorca and Menorca (Western Mediterranean) to control the population of rabbits. This species contributed to the local disappearance of the endemic Balearic lizard (*Podarcis lilfordi*) and the endemic midwife toad (*Alytes muletensis*). The Balearic lizard currently survives only on some islets surrounding Mallorca and Menorca, while the Balearic midwife toad survives only in the inaccessible mountain torrents of Mallorca.

Recent research identified rats (*Rattus* spp.) as a major invasive key species, whose effects on natural ecosystems have been frequently underestimated. Three species of rats associated with humans (*R. rattus, R. norvegicus*, and *R. exulans*) invaded a wide range of ecosystems, including a large number of islands. Rats have been incorporated onto the islands through transport in human vessels, although—after their landing on remote islands—their active colonization in the surrounding islands or islets (by swimming there) has been also recorded, amplifying their effects on the natural ecosystems. The effects of rats on seabird populations and on some populations of endemic rats have been documented elsewhere. Nevertheless, the impact of rats may have been much greater than initially established. Recent studies of Terry Hunt suggest that the impact of *R. exulans* through consumption of the seeds of the *Jubaea* trees on Rapa Nui (Eastern Island) probably caused the total deforestation and the complete transformation of the ecosystems of the island.

### Historically Recent Invasions

The invasions over the past several centuries represent a further step in the globalization of nature. New methods of transportation as well as the modern technologies developed after the Industrial Revolution have created new opportunities for invasive species. As an example, the ballast water of ships has introduced hundreds of new planktonic species in oceans around the world. Also, some benthonic invaders traveled in the hulls of ships (e.g., *Cordylophora caspia*, a hydrozoan that spread throughout the world from the Caspian Sea, acting as a competitor against other benthonic species).

Large engineering projects also resulted in the invasion of species. A clear example is the Suez Canal, built to link the Red Sea to the Mediterranean Sea (1869). To date, more than 300 marine species from the Red Sea have invaded the Mediterranean. Some of them have proved to be totally negative for the native species (e.g., *Siganus rivulatus*, an introduced fish that is producing very harmful impacts on the marine ecosystems of the eastern Mediterranean).

The rise in maritime traffic increases the possibility of transport and transference of species among harbors. A noticeable case is the arrival of the brown tree snake, *Boiga irregularis*, on Guam,
probably as a stowaway in military cargo from the Papua New Guinea area during the post-World War II years. This highly poisonous species is transforming the whole Guam ecosystem, and it is responsible for the extinction of endemic birds.

Introductions of species to be exploited for fishing and hunting have also been common in recent decades (mainly, bovids have been introduced in several parts of the world, with a negative impact on native vegetation). A well-known example is the introduction of rabbits in Australia. The rabbit population increased at an alarming rate, causing a significant impact on the Australian vegetation. Similarly, the release of several species of river crabs and fishes for fishing purposes in several European countries has significantly affected the populations of native species of these vertebrates by predation and competition.

**The Future**

Although efforts to control invasive species and possible new introductions have been widely implemented by governments, unfortunately only a small proportion of cases of human-induced invasions have been favorably resolved. It has been suggested that, apart from preventing the arrival of more individuals of introduced species, information to the public in general, integration of prevention and control actions, good knowledge of the invasive species, and direct eradication are the best tools to manage invasive species. Specific laws to control importations can also be enacted to stop the invasion of species originated by common market policies. Recently, it has been documented that different snake species invaded the Mediterranean island of Eivissa, which was originally without them. These snakes have been introduced through the import of olive trees from Europe for gardens. Local authorities cannot control the free market existing in the European Community, and consequently, future invasions of aliens may unstoppable.

_Pere Bover and Josep Antoni Alcover_

**Further Readings**


**Humanistic Geography**

*Humanism* is a term that encompasses a variety of philosophical positions that go back to the Renaissance, during which scholars such as Erasmus and Petrarch offered views of the social world that put people in the center, in contrast to the prevailing religious interpretations. Closely associated with humanism is hermeneutics (from Hermes, the Greek messenger of the gods), which is essentially the study of meanings; originating from medieval attempts to find the one “true” meaning of the Bible, hermeneutics was extended to include the multiplicity of meanings inherent in all literary texts and social actions.

**A Very Brief History of Humanistic Thought**

Two closely related approaches to humanistic thought have characterized it over time, phenomenology and existentialism. Both are concerned with the shape of human experience, the nature of subjectivity, and there is considerable overlap. Whereas phenomenology tends to emphasize the nature of human experience and meaning, existentialism is more often concerned with the ethical conduct of life.

Several giants in the history of philosophy invoked these lines of thought. The Danish Christian existentialist Søren Kierkegaard (1813–1855) offered a Romantic critique of the Enlightenment,
claiming that objectivity is a myth and that all people faced an agonizing choice between faith and reason, the sacred and the profane, and ethics and pleasure. Edmund Husserl (1859–1939) proclaimed a transcendental phenomenology, noting that the view of science as an objective map of the outer world reduced the human observer to a passive receptor. Objects do not have meanings in and of themselves, he argued; rather, meanings are constructed by the human mind. Husserl called for a science of phenomenology that would strip away the biases that the mind created in its perceptions of the world to reveal the essence, the reality of things in themselves. Martin Heidegger (1889–1976) asked the apparently simple question “What does it mean to be?” and offered a very complex answer. His view rested on the notion of the hermeneutics of “being” (Dasein)—the understanding of which meant an escape from abstract theorizing. Jean-Paul Sartre (1905–1980) attempted a merger of existentialism and Marxism, noting that in contemporary capitalism the human condition is depersonalized and alienated. Essentially, all these views maintain that objectivity is a hurdle to effective understanding and that there is no privileged conceptual vantage point; every view is a view from somewhere and is inescapably laden with biases. We cannot know the world except for the meanings people give to it. Human subjectivity is thus not a barrier to understanding the world but the only route to know it. Meanings are essentially arbitrary phenomena, and logic cannot inform our moral choices. Despite this predicament, as Sartre noted, humans are “condemned to freedom”—that is, they must make choices even if there are no firm grounds for doing so.

Central Tenets of Humanistic Thought

The project of a humanistic social science was thus to put people back in the center of social analysis, to reveal the thing that makes people human—namely, consciousness. Social science has long had a poor conception of the human subject, a flaw humanism attempts to overcome. It is consciousness that makes us subjects rather than objects—that is, allows us to be actors in the world with will and volition. Mapping human consciousness allows us to move past sterile models of human behavior such as Homo economicus and recover the sensuous nature of experience—the ways in which the self, the environment, and others are framed symbolically. This task involves some understanding of intentionality, our deeply human desires and motivations, and our anticipations and expectations.

Uncovering the multiple dimensions of human consciousness, however, is no simple task. It is essential to avoid simplistic and biologically reductionist notions of “human nature.” In the broadest sense, consciousness is what makes us human. In some respects, human consciousness differs qualitatively from that of animals (e.g., in our sense of self, time, humor, death), although with many primates this difference is a matter of degree. Constructing a humanistic understanding of consciousness has also invoked various psychological understandings of sensation, perception, and cognition, leading to intersections with behavioral approaches. Consciousness includes our emotions and memories, pleasures and fears, sense of sexuality, hopes for the future, and more, both rational and irrational. This view sees human beings as active, creative actors and stresses their constructive role in making the world. Social reality does not simply happen to individuals “behind their backs” or “above their heads”; they make the world that makes them. Humanistic social science is thus unapologetically anthropocentric and antinaturalist (it objects to using the same means to understand the natural and social worlds) and antideterminist (noting that people’s actions render social structures ever changing and contingent).

Humanistic thought emphasizes the central role of language, as a set of signs that we use to negotiate the world and share meanings. Language is the means by which we bring the world into consciousness, and thought is always linguistically structured. As linguists and philosophers such as Wittgenstein and others have demonstrated, language is an opaque medium of understanding with a structure of its own. There is no language-free theory, and language limits and constrains the ways in which meanings are constructed, at times letting them escape their authors. The intersections of humanistic thought and literature in the form of textual deconstruction allowed every system of signs (e.g., a text, a landscape) to be pulled apart.
Like positivism and empiricism, the humanistic approach begins with the individual’s experience in the construction of knowledge. The task of social science is to enter into another’s taken-for-granted world—to see reality through other people’s eyes and acknowledge their view as a valid source. Truth is found in the subjective meanings that people assign to their worlds, and explanation is the recovery of their intentions. Humanism thus advocated a self-consciously empathetic social science that did not strive for the holy grail of objectivity but rather confronted its own inevitable assumptions and biases. This approach forces researchers to acknowledge both the subjectivity of the observer and the subjectivity of the observed, to question their own assumptions and biases, rendering the old subject/object dichotomy false and inserting the researcher into the research process. In doing so, humanism confronted social science with the need to clarify the ethics and morals of the observer, making clear his or her positionality in the research process. It also legitimated the use of qualitative research methods that sought to uncover the views of subjects, such as participant observation and case studies.

Humanistic Geography

Humanistic thought has a long history in the discipline of geography. In the early 20th century, French cultural geography owed much to Paul Vidal de la Blache, who studied the unity of culture and landscape in terms of the lifestyles (genres de vie) in small rural areas called pays, uniting land and life through an understanding of how consciousness and the Earth are deeply intertwined. In the 1960s and 1970s, major contributions to the American literature on humanistic geography were made by several authors. Edward Relph was concerned with the cultural impacts of mass production and consumption, the homogenization of capitalist landscapes, and the resulting alienation. Anne Buttimer introduced the notion of life-worlds, a phenomenological recovery of genres de vie that took as its point of departure the multiple ways in which consciousness was preconsciously sutured to the locale in the intimate rhythms of everyday life. David Lowenthal wrote on landscape tastes and perceptions and the relationship between history and cultural heritage. David Ley offered richly detailed urban ethnographies of the inner city and social geographies of Canadian cities.

Yi-Fu Tuan, who coined the term humanistic geography, holds pride of place in this pantheon. Tuan’s contributions included the widely popular notion of “sense of place,” the highly subjective set of feelings and impressions that individuals attach to specific locales. In this reading, places are intangible webs of meaning, not simply physical points. Sense of place, for example, makes a house into a home or a church into a locale saturated with religious overtones or defines a gang’s turf. Tuan applied this set of notions, broadly grouped under the label topophilia, to studies of nature versus wilderness, spaces of pain and torture, sacred places, patriotism, pets, and more. This line of thought offered a useful differentiation between space and place. In part, the difference is a matter of scale. Space generally concerns broader domains than that which individuals experience on a daily basis. However, space in the Western tradition is often used in a highly abstract sense, such as a Cartesian plane or isotropic plains used in mathematical models. In contrast, place refers to smaller, localized, more intimately experienced, intangible depositories of experience. The shift from space to place—one of the major contributions of humanistic geography—saw a transition from abstract, disembodied space to the embodied, erotic, personal, and pungent places of individual worlds. Such a move exhibited a concern with particularity and specificity rather than generality and made little effort to search for “general laws.” Humanistic geographers were interested in what makes places unique, how they enter the human consciousness, and how that consciousness in turn constructs places through interpretation. In doing so, they opened to geography linkages to hitherto closed domains, such as landscape architecture, cultural anthropology, the sociology of the self, and the arts and humanities.

Another topic legitimized through humanistic geography was the geography of identity and the body. While classical theories of the human subject portrayed identities as unitary and stable, the phenomenologists argued that identity is a multiplicity of unstable, sometimes contradictory, context-dependent traits that change over time and space. Identities are both space forming and space
formed—that is, they are inextricably intertwined with geographies in complex and contingent ways. Likewise, they explored the multiple ways in which identity, subjectivity, the body, and place are tied together. The interface between body and mind is an ancient topic of philosophical consideration; the fact that we both have bodies and are bodies confronts us with the nebulous intersections of mind and matter. The body is where the mind resides—the locus of consciousness, tangible and corporeal evidence of its existence, giving existential and phenomenological depth to lived experience. While bodies typically appear as “natural,” they are in fact social constructions deeply inscribed with multiple meanings, “embodiments” of class, gender, ethnic, and other relations. The body is the primary vehicle through which the prevailing economic and political institutions inscribe the self, producing a bundle of signs that encodes, reproduces, and contests hegemonic notions of identity, order and discipline, morality and ethics, and sensuality and sexuality.

In insisting on the primacy of the intentional subject, humanistic scholars were adamant that geographies and landscapes are always authored—that is, they are created by people, who give meaning to them. This position was very much at odds with rival perspectives, including the impersonal geometries of positivism. Humanists challenged behavioral geographers to explore not simply the actions of people but also their intentions, avoiding simplistic black box models such as H. eco

nomicus. Finally, humanist thought mounted a serious challenge to Marxism, pointing out its flawed conception of human subjectivity and questioning its economic determinism and teleological view of history and geography, in which people are represented as finders of a world already made. Instead, humanists argued, the social world is open-ended and contingent, forever in the process of becoming.

Humanistic thought, however, also had its critics. Marxists and others pointed out that it offered no account of social relations, of class, power, and production. Moreover, humanism’s notion of the subject, however rich, was a largely asocial, undersocialized account of individuals in purely personal, not interpersonal, terms. For example, a dwelling is not just a site of caring and memories but also a locus of social reproduction, family relations, patriarchy, and power. Moreover, by being silent about social relations, humanistic thought lapsed into an uncritical view of the world as simply structured by choice, a mythologized vision of “free will” devoid of social constraints. Humanism’s critics argued that methodologically this approach was deeply flawed, offering, for example, no means of validating, confirming, or disproving its claims. Some even held that humanistic thought was opposed to science. These problems led critics to argue that humanism sufficed as a critique of other positions—a way of unmasking presuppositions—but not as an alternative.

Humanistic thought made great contributions to geography, helping revive cultural geography and forcing researchers to take seriously the complex question of human consciousness. It jettisoned the myth of objective research and made explicit discussion of values and biases an integral part of the research process. In the end, humanistic geography, faced with serious critiques of its own, was largely integrated into other paradigms such as structuration theory and the various poststructuralist perspectives that arose in the 1980s and 1990s.

Barney Warf

See also Body, Geography of; Buttimer, Anne; Ethics, Geography and; Everyday Life, Existentialism and Geography; Human Geography, History of; Identity, Geography and; Ley, David; Participant Observation; Phenomenology; Place; Qualitative Methods; Relph, Edward; Sense of Place; Situated Knowledge; Social Geography; Symbolism and Place; Tuan, Yi-Fu

Further Readings


Humanistic GIScience aims to integrate knowledge derived from the humanistic tradition with key issues related to spatial data representation, analysis, and visualization in the context of GIScience. Rather than attempting to maximize accuracy by minimizing or even eliminating uncertainty, humanistic GIScience incorporates the human subjective and even imaginative dimensions of experience in the process of spatial data handling.

Recent developments in ubiquitous computing have made almost everything computable with explicit geotagging. The goal of humanistic GIScience is to build dialogues with the humanistic tradition to understand human life in the context of social or human-centered computing. Recent works on the integration of indigenous knowledge, feminist perspectives, public participation GIS, collaborative GIS, and GIS-based art practices into the conventional GIS modeling processes are examples of humanistic GIScience in practice.

The search for a new means of analysis and modeling via computers has been increasingly entwined with a persistent search for the deeper meaning of such activities. As the aesthetic and humanistic traditions within GIScience expand, artists’ renditions of reality in novels, poems, paintings, movies, music, and songs can be rich sources of inspiration for GIScientists to explore alternative conceptualizations of space, place, time, environment, region, and scale. In addition to representations of space framed by Euclidean geometry, humanistic GIScience attempts to find novel ways to handle the textures of place as articulated in the humanistic tradition. Furthermore, the development of humanistic GIScience is transforming geospatial technologies into a locative media for affective practices through self-expression and storytelling. For example, practitioners of feminist GIS such as Mei-Po Kwan have developed GIS that incorporate the geography of women’s fear into their representations of urban landscapes. Others have attempted to combine GIS with local ethnographies that incorporate indigenous forms of environmental knowledge. Yet others develop neogeographic, Web-based “mash-ups” that rely on volunteered data to map various phenomena, including local place perceptions.

In many ways similar to the development of humanistic geography, humanistic GIScience also aims to put people back at the center of spatial analysis. Along with critical GIScience, humanistic GIScience has significantly broadened and enriched the theoretical foundations of GIScience. The pluralistic theoretical approaches have precipitated diverse GIS practices in the age of Web 2.0, in which we can document and record individual experiences and share them instantaneously with a global audience.

The development of Web 2.0 technologies in general, and especially user-generated content in the form of volunteered geographic information (VGI), has shifted the focus of GIScience from handling geospatial information to handling information geospatially. The Web offers a brave new world of geotagged information unprecedented in human history, in a variety of multimedia forms from text (blogs), to photos, videos, and traditional geospatial data, to social networking sites such as Facebook and microblogs such as Twitter. These developments constitute a very rich data source on human subjectivity and behavior, which may further expand the development of humanistic GIScience and affective geospatial practices.

In addition to the vast multimedia data available, recent breakthroughs in mapping and visualization technologies offer additional resources for the development of humanistic GIScience. The launching of Google Earth and Google Map StreetView, for example, has shifted the predominant orthogonal view to an oblique view, which is more natural and intimate to most people. For most GIS users, the dominant orthogonal view has promoted the kind of geography that is
quantitative, objective, and analytical, whereas the oblique view will retrieve the kind of geography that is more qualitative, subjective, and interpretative. This means that GIScience will need not only the part of geography that is rooted in the tradition of spatial analysis (means of analysis) but also the part of geography that is anchored in the tradition of hermeneutic interrogation (meanings of analysis). Recent works in emotional mapping best embody the spirit of the emerging humanistic GIScience practices.

The development of humanistic GIScience has ontological as well as epistemological implications as it confronts GIS users with the questions of what exists/can be known and how we know it. Instead of making simplistic, dichotomous assumptions regarding the researcher and the researched, humanistic GIScience has reinserted the user/researcher at the very center of the research enterprise. Consequently, the emergence of humanistic GIScience has also stimulated further discussions on theories of truth in GIScience research. Besides coherence, correspondence, consensus, and contextual theories of truth, practices following the humanistic GIScience will expand the recent discussion and debates on non-representational theory and the performative theory of truth—what is considered true is intimately connected to the practices and performances developed by users employing various technical means.

While the development of GIScience was concomitant with the development of GIS, GIScience is no longer reliant on these tools for its existence and meaning. With the development of a humanistic component, GIScience became more than a computational science in search of new algorithms. In fact, GIScience is also emerging as a humanistic science in search of meanings for its computations and an area for speculating about what lies beyond the limits of computation—GIScientists’ new terrae incognitae. At the interface of computing technologies with humanistic scholarship, we can expect groundbreaking development in the future.

Daniel Z. Sui

See also Collaborative GIS; Feminist Methodologies; Humanistic Geography; Kwan, Mei-Po; Neogeography; Ontological Foundations of Geographical Data; Ontology; Public Participation GIS; Situated Knowledge; Sui, Daniel

Further Readings


Human rights touch almost every aspect of life. Taken as a whole, they suggest a way of living together in peace, dignity, and freedom. A geographical perspective of human rights attempts to answer the question of whether people have the right, literally, to a place in the world. At its core, the concept of human rights involves political, cultural, economic, social, or environmental processes where issues of oppression are central to human struggles that are inextricably tied to particular places. As such, the major themes of locality, movement, and nature-society relations in the discipline of geography play an important role in any scholarship based on human rights. The late 20th and early 21st centuries have seen the emergence of human rights as a formal field of study that focuses mainly on the abuses of the state in oppressing its residents and citizens. In the context of international law, global awareness of the unjust treatment of people by governments or institutions is now commonplace. International entities such as the United Nations, Human Rights Watch, and Amnesty International now play a large role in revealing these abuses and pressuring governments to stop human rights abuses.

The initial concepts of universal human rights reach as far back as the Enlightenment, but it was the Holocaust in the mid 20th century that became the impetus for modern conceptions of human rights on a global scale. Engaging in mass violence, torture, and the mistreatment of human beings was certainly not a new aspect of humanity. But the rise of modern technology took human cruelty to new and frightening levels, giving rise to a systematic genocide that remains unparalleled in human history. As a direct result of the Holocaust, the United Nations adopted the Universal Declaration of Human Rights in 1948. The Declaration sets out a list of universal human rights, depicting them as “a common standard of achievement for all peoples and all nations.” Among these rights are the right to life, the right not to be tortured or enslaved, the right to seek asylum from persecution, and the right not to be subjected to arbitrary arrest, detention, or exile. The Declaration also grants freedom of thought, expression, and religion. The cultural rights laid out in the document include the right to marriage, education, employment, food, and shelter. Although in a legal sense the Declaration is a nonbinding document, it has grown to become a major factor in international law since its adoption. In fact, many of the rights in the Declaration formed the groundwork for several regional human rights documents, such as the European Convention of Human Rights, the African Charter of Human and Peoples Rights, and the Helsinki Accords. While the Declaration has succeeded in extending human rights to some places (mostly Western democracies), it has not succeeded in extending rights to other places in the world. Indeed, the late 20th and early 21st centuries have seen their share of human rights atrocities in many places, including Guatemala, Cambodia, China, the Soviet Union, Tibet, Bosnia, and the Darfur region of Sudan, as well as the “disappearances” in Argentina and Chile, the death squad killings in El Salvador, and the genocide in Rwanda.

One important aspect involving a geographical examination of human rights is the selection of appropriate spatial scales of analysis. The selection of which level of analysis to use will, to a large extent, help define the degree and extent of the human rights abuses. Exercising one’s human rights in a local context may require access to physical space, an important geographic concern. For example, exercising one’s legal rights requires access to a courtroom, and implementing one’s political rights requires access to a voting booth. The right to education requires access to schools. Connections between human rights and physical access may also play out at larger geographical scales, such as differences in access to health care between urban and rural populations. In the United States, spatial scale plays a role in accessing the right to marriage for same-sex couples, as some states legally allow such arrangements and some do not. Physical access and spatial scale also play a role in reproductive rights for women throughout the world, restricting access to birth control and abortion in some places but not in others.

Situating human rights issues within their local contexts requires a geographical approach to reveal the overlapping networks of politics, economics, and law. For example, the 35-year-old “war on drugs” waged by the U.S. government reveals broad
geographical disparities in the implementation of policies related to drug-related arrests, imprisonment, and law enforcement, disproportionately affecting low-income communities of color. Since 1980, there has been a substantial divergence in racial composition related to drug offenses, as both the numbers and the proportions of African Americans arrested and imprisoned for these crimes have far outpaced those of whites. Nationwide, black men are sent to prison on drug charges at 13 times the rate of white men. Additionally, there are broad geographical variations among the nation’s cities related to the degree of drug-related offenses, suggesting that local priorities and politics related to law enforcement may be influential in producing uneven geographies of political, social, cultural, and economic rights related to law enforcement within the United States.

The processes of globalization in the 21st century indicate that the causes of and solutions to human rights problems are more complex and dispersed. One country sells weapons or buys diamonds, which perpetuates conflict elsewhere; trade policies create poverty; closing borders to migration perpetuates a spatial unevenness of economic burdens and human rights abuses; and environmental abuses cause distant disasters. But it is at the scale of the nation or state that people are far more apt to be harmed by their own government than by other actors. These abuses take the form of political or military repression, judicial corruption, economic discrimination against minorities, and so on. Abusive governments and corrupt elites often appeal to “state sovereignty,” insisting on noninterference in internal affairs whenever they face international pressure to reform. The United Nations and other international bodies have been roundly criticized for standing by, or even defending, the prerogative of rogue governments to do what they wish by making claims of sovereignty, noninterference, or regional solidarity. Many observers, such as Amnesty International, argue that the United States’ recent record on human rights abuses, mostly committed in the name of countering terrorism, has crippled its ability to respond effectively even where it seeks to uphold human rights. Consequently, ongoing human rights abuses and mass atrocities continue in countries such as Afghanistan, Iraq, Iran, North Korea, Cuba, Colombia, the Congo (Zaire), Georgia, Israel and the occupied Palestinian territories, Somalia, Sri Lanka, and Sudan. Other powerful and influential nations have also been criticized for allowing regional political repression to continue, such as China for its occupation of Tibet and India for its reluctance to address government repression in Myanmar/Burma.

Geography offers a means to help understand and transform the way human rights are defined, interpreted, and implemented. Human rights can never be “guaranteed” but instead represent continuing struggles by making claims on geographical space to build a more just world. Whether one chooses to examine human rights at the local, regional, or global scale, a geographical perspective is necessary to reveal the unjust distribution of society’s benefits and burdens.

*Thomas Chapman*

*See also* Citizenship; Environmental Justice; Genocide, Geographies of; Justice, Geography of; Political Geography; Social Justice

**Further Readings**


Alexander von Humboldt is commonly called a “Renaissance man” because he was so talented in many subjects, notably natural history, geology, mining, engineering, anthropology, cartography, botany, political science, and diplomacy. Humboldt’s inquisitive mind and ability to master many separate subjects dovetailed with the social conditions of the era in which he lived. His times, broadly called the Enlightenment, valued science and empirical observation while challenging older ways of viewing the world. Humboldt was no mere observer of those times; he in fact shaped them through his extensive studies and travels. Although German by birth, he represented a new class of individuals we today call citizens of the world. Although the modern discipline of geography emerged after Humboldt’s death, geographers quickly realized that Humboldt was one of the pioneers of their field.

Friedrich Wilhelm Heinrich Alexander von Humboldt was born on September 14, 1769, in Berlin. As a child, Humboldt was tutored by highly trained scholars, and he later studied at two universities, Frankfurt-an-der-Oder and Göttingen. When he was 22 years old, Humboldt entered the Freiburg School of Mines, where he studied geology and mining. On graduating, he became assessor of mines in Bayreuth. Given Humboldt’s gift for observation and interpretation, as well as the practical application of knowledge, he advanced rapidly. Humboldt’s charismatic personality and intelligence enabled him to interact with learned individuals throughout Europe. The fact that Humboldt was fluent in several languages (his brother Wilhelm was a linguist) also helped him build an international network of colleagues and associates. In 1796, on the death of his mother, Humboldt inherited a fortune. That wealth freed him to engage in his true passions, exploration and science. Given Humboldt’s enthusiasm for unexplored places, he sensed an opportunity to make major scientific discoveries in the Americas. At that time, Europe controlled most of the Americas, with the exception of the recently created United States.

By the late 18th century, Humboldt was poised to become one of the world’s great scientific explorers. Now that he had developed connections in high places, including Spain, he called on them to open doors for him in the Americas. In 1799, after receiving unprecedented permission from Spain, Humboldt departed for the Caribbean and South America in the company of the noted botanist Aimé Bonpland. Their goal was to observe the environment in order to determine its potential productivity. However, Humboldt also explored these places for the pure joy of making scientific discoveries. On arriving in the New World, the expedition traveled deep into Northern South America, where Humboldt and his colleague collected thousands of geological, botanical, and zoological specimens while also making hundreds of detailed geomagnetic and celestial observations. Humboldt’s expeditions also had a cultural and economic focus. In late 1800 and early 1801, Humboldt visited Cuba to study the slave-based economy of the sugar plantations, which he found repugnant to his liberal philosophy.

Humboldt’s success on these expeditions can be credited to his ability to select, and listen carefully to, the best native guides and local contacts. By 1802, Humboldt had explored Western South America in the vicinity of Ecuador’s Mt. Chimborazo, whose 5,759-meter summit he managed to climb (setting a world record in the process). Humboldt next headed eastward into the upper reaches of the Amazon basin, thence westward into the former Inca strongholds of the Peruvian Andes, where he was intrigued by the diversity of the indigenous cultures. While in Western South America, Humboldt studied the cold ocean current that would later bear his name (though it is now called the Peruvian current). Because Humboldt was also a noted cartographer and illustrator, his reports contained a wealth of maps and observations, which he made available to Spain (and other countries). This was a major accomplishment, but Humboldt was not the first European scientific explorer to study South America. Consider the controversial Alesandro Malaspina, who had conducted explorations about a decade earlier (1789–1794). However, whereas Malaspina wound up in a Spanish prison as an alleged spy, Humboldt’s motives were never seriously questioned.

When his observations concluded in South America, Humboldt headed north to Mexico, where he spent about a year making field observations and studying the maps in the archives.
Figure 1: Map of the Kingdom of New Spain by Baron von Humboldt 1803, published in 1812.

Source: Maps of the American West, Department of Special Collections and University Archives, McFarlin Library, University of Tulsa, Tulsa, Oklahoma.
Simultaneously, Humboldt engaged in a wide-ranging political commentary about conditions pertaining to Mexican society and culture. It should be noted that Humboldt traveled widely with the blessings of Spain at a time when its New World possessions were about to be challenged by both outside powers and internal rebellion. In that sense, Humboldt’s reports not only provided a remarkably candid assessment of conditions in New Spain but also a blueprint for those seeking opportunities to seize these possessions from Spain.

Before returning to Europe in 1804, Humboldt visited Philadelphia and Washington, D.C., where he was hosted by President Thomas Jefferson. During this visit, Humboldt provided Jefferson with a copy of his “Map of the Kingdom of New Spain” (Figure 1), which revealed the state of knowledge about the North American West and excited much interest on both sides of the Atlantic. On returning to Europe, Humboldt lived in Paris and then returned to Berlin. He spent much of his time writing his epic Voyages aux régions équinoctiales du nouveau continent, fait en 1799–1804—a huge book that paradoxically drained his fortune while resulting in his enduring fame. In that book, Humboldt propounded many scientific concepts pertaining to both botany and geophysics. He was the first person to demonstrate that points of equal temperature could be mapped using a line—the now-familiar isotherm—and he also introduced the concept that vegetation is zoned vertically (i.e., by altitude as well as latitude). Humboldt was a master cartographer and illustrator who invented new ways of portraying phenomena such as vegetation distribution, volcanism, and geomagnetic forces.

In his later years, Humboldt continued to write about the world around him in a way that combined science, philosophy, and spirituality. His Cosmos is a classic in the literature, revealing Humboldt’s vision of placing science in a philosophical perspective. Given his well-publicized travels, numerous books, and innumerable lectures, Humboldt became a legend in his own time. Throughout the early to mid 19th century, in fact, aspiring scientists tried to link their careers to his. An endorsement by Humboldt was as good as gold; small wonder that his name became synonymous with genius and authority. In 1859, Humboldt died in his native city of Berlin, leaving a legacy that is both imposing and inimitable.

In retrospect, Humboldt and his work have become something of a Rorschach test. Whereas Humboldt was almost universally, and simply, known as a great “naturalist” and “scientist” in his own lifetime, things began to change by the mid 19th century. As disciplines such as botany, geology, and meteorology became established, the practitioners of those disciplines came to focus on Humboldt’s work in those particular areas. Naturally, given their interests, Humboldt was adopted as one of their own. Given the rise of professional geography in the 20th century, with its emphasis on how to explain the distribution of phenomena and how to decipher the interconnections between nature and humankind, it is not surprising that Humboldt was soon adopted as one of the pioneers of modern geography. He could, after all, deduce the character of a place based on its appearance and location, and he could also brilliantly interpret phenomena in spatial terms. Those are the hallmarks of a geographer, but then again the things that Humboldt encountered—rock formations in mountain ranges, individual plants and animals, human inhabitants, even cultural attitudes—fascinated him in their own right. Given the recent negative reinterpretations of European colonialism, it is not surprising that some critics, including postcolonialist geographers, consider Humboldt an imperialist at heart. However, a close reading of Humboldt’s reports suggests that he was as subversive as he was complicit. Call him what you will, Humboldt above all serves as a reminder that the reputations of historical figures as well as the disciplines they represent are constantly evolving.

Richard V. Francaviglia

See also Exploration; Human Geography, History of; Ritter, Carl

Further Readings

Humidity is a parameter representing the amount of water vapor in the air. This is expressed in numerous ways: relative humidity, mixing ratio, specific humidity, and absolute humidity. Relative humidity is the most commonly used term when we refer to humidity in the field of geography and in our daily lives. Relative humidity is the ratio of the water vapor content that is actually present in the air to the water vapor content in the saturated air at a prescribed temperature, and its values are given as a percentage. As a definition, relative humidity is expressed as the ratio of the actual vapor pressure ($e$, the partial pressure of water vapor) to the equilibrium or saturation vapor pressure ($e_s$, the vapor pressure of the saturated air) and is given as $\text{RH} = \frac{e}{e_s} \times 100$.

Alternatively, we are able to consider the parameter as the ratio of the actual mixing ratio ($q$; described later) to the saturation mixing ratio ($q_s$). A condition in which air is completely saturated has 100% relative humidity. Air with relative humidity higher than 100% is called supersaturated. Relative humidity varies with water vapor content and/or temperature. In other words, relative humidity varies with temperature even when the total amount of water vapor does not change. This is because the saturation vapor pressure depends on temperature, whereas actual vapor pressure does not.

Relative humidity has an inverse relationship to the diurnal variation of air temperature near the ground surface, and therefore, its value becomes smaller as temperature increases. In urban areas, the surface air temperature is generally higher, and lesser evapotranspiration occurs than in its surrounding areas. As a result, relative humidity has a tendency to be lower in urban areas. Relative humidity can be measured in the field using instruments such as sling hygrometers.

Other parameters that represent humidity—the mixing ratio, specific humidity, and absolute humidity—are defined from a different perspective to relative humidity as these depend on water vapor content but are independent of temperature.

The mixing ratio ($q$) is the ratio of the mass of water vapor to the mass of dry air, whereas specific humidity ($s$) is represented by the ratio of the mass of water vapor to the total mass of air. Consequently, specific humidity has almost equivalent values to the mixing ratio. These variables are presented here in kilograms per kilogram but are usually expressed in grams per kilogram. The mixing ratio ($q$) and specific humidity ($s$) are both functions of vapor pressure ($e$) and total pressure ($p$). Hence, these variables are given as $q = 0.622 \frac{e}{p - 0.378e}$ and $s = 0.622 \frac{e}{p}$. On the other hand, absolute humidity gives the water vapor density in the air and is expressed in kilograms per cubic meter.

Besides these parameters, other variables such as dew-point temperature and dew-point depression (temperature/dew-point spread) also represent the amount of water vapor in the air. These variables are generally used in the fields of weather forecasts and atmospheric sciences rather than in the field of geography.

Hiroyuki Kusaka

See also Atmospheric Moisture; Climate: Tropical Humid; Clouds; Precipitation, Global; Precipitation Formation
More than 60 yrs. (years) after the human right to adequate food was formally declared by the United Nations (UN), hunger remains a characteristic feature of many people in the capitalist world system. Hundreds of millions of people, from Chicago to Mumbai and from Russia to Malawi, are unable to reliably access and consume an adequate diet. This condition exists, strikingly, in a world where food production and trade have easily outpaced population growth for decades. For example, in 2006, agricultural output (not all of it food) was nearly 40% higher than in 1990, a period during which the world’s population increased by around 25%. The number of hungry people in the world grew during that same period, and while hunger declined in relative terms in all the world’s major regions, the recent price rise in food and the worldwide economic crisis threaten to reverse that encouraging trend. This entry discusses the definition and measurement of hunger, the world geography of undernutrition and malnutrition, the concept of food insecurity, the impact of globalization and urbanization on world hunger, and the shift of responsibility for hunger from government to private individuals and organizations.

**Defining and Measuring Hunger**

In a very basic sense, hunger is the experience of not being able to consume enough and the right kinds of food. While this seems straightforward enough, the identification, explanation, and alleviation of hunger are fraught with disagreements over conceptual issues related to the socially and culturally complex and dynamic relationship between human beings and food. An effort to produce a body of scientific knowledge related to that experience emerged with the modern state and its imperative to measure, quantify, and, thereby, manage and regulate the population. For well over a century, intellectual debates over the concept and phenomenon of hunger have concerned questions of objectivity, universality, reliability, validity, and statistical precision. To take one example, in the late decades of the 1800s, British nutritionists, social reformers, government officials, and colonial administrators considered local food practices—whether they reflected “rational” behavior or not—and optimal diets as they argued over the discovery of universal standards by which to determine who in Britain and its colonies was “hungry” and who had died as a result of “starvation.” In the United States, social, political, and policy debates since the 1960s have increasingly revolved around questions about the validity and reliability of hunger data, leading to a broad, state-sponsored effort to develop methods for the scientific measurement of hunger. These examples also serve to illustrate the point that scientific knowledge about hunger, no matter how technically precise, is infused with, and shaped by, politics (power relations), culture (social meanings), and the environment (human relationships with biophysical systems). In short, the task of defining and measuring hunger confronts powerful social, political, economic, and environmental geographies in the relationship of people to food and, therefore, in what constitutes hunger. In the early 2000s, conceptual debates about hunger have settled on three prominent, not uncontested, understandings of hunger.

**The World Geography of Undernutrition and Malnutrition**

The two most commonly recognized forms of hunger are undernutrition and malnutrition. Very basically, undernutrition occurs when a person is unable to consume enough calories to remain healthy and active on a continuing basis, depending on her or his age, sex, height, age, and daily physical exertion. Malnutrition specifies a person’s inability to consume a nutritionally balanced
diet. This can involve either deficient or excessive consumption of particular nutrients, such as proteins or carbohydrates. Both of these kinds of hunger result in a range of physical and mental effects on the body, most notably stunting (low height for age), wasting (low weight for height), underweight (low weight for age), impaired cognitive development, greater susceptibility to disease and injury, and, in the case of malnutrition, obesity.

The world maps of undernutrition and malnutrition are typically drawn using estimates of deficient calorie, vitamin, and protein consumption; stunting; underweight children; and infant mortality. Deficient calorie consumption is the most common indicator used to examine the global distribution of hunger. The UN estimates that more than 900 million people, slightly less than 15% of the world’s total population, do not consume enough calories on a daily basis. More than a third of those live in the South Asian countries of India, Bangladesh, and Pakistan, and another 14% of the world’s population of undernourished people live in China. In relation to national populations, inadequate calorie consumption is highest in countries in Central, East, and Southern Africa, where more than one third of the people are undernourished. In some countries, notably the Democratic Republic of the Congo, Chad, Burundi, and Eritrea, the rate of undernourishment exceeded 50% a decade ago and has increased during the intervening period. Especially high rates are also found in South Asia, the
Inasmuch as food insecurity is a subjective and distinctly contextual condition—that is, one for which objective and universal indicators do not exist—it is difficult to map at the global scale. The way it is experienced, and the reasons why, differ significantly from place to place. For example, food insecurity exists in the anguish of a mother in India who, without other recourse, feeds her children imported food that was processed without considering her religious conventions; in the fear of a Mexican farmer that by having to grow genetically modified maize he is subjecting his family to adverse health effects and undermining the sustainability of his farm; and in the social alienation of a Canadian or American man who lacks income and must obtain food through an emergency kitchen.

The Globalization, Urbanization, and Depoliticization of Hunger

The geography of hunger exists not only in its spatial patterns of incidence but also in the underlying causal processes. Several broad geographic processes are particularly relevant in the early 21st century. The first involves the tendency toward a liberalized and globalized agro-food system involving corporate concentration in food production, processing, distribution, and retailing and the opening of national food sectors to imports and investment capital from multinational firms. This process is linked to a general decline in subsistence and locally oriented farming (a majority of the world’s population still earns a livelihood by producing food) and the increasing inability of consumers, particularly those with low incomes, to determine what they eat. The latter, paradoxically, is associated with rising obesity among poor people, who often reside in what policymakers and scholars refer to as “food deserts”—that is, rural areas and central-city neighborhoods, where a range of affordable fresh foods is effectively unavailable due in large part to a reduction in the number of local grocery stores as a result of changes in the retail industry.

Table 1 Undernourishment by region, 2009 (in millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Undernourished (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed countries</td>
<td>15</td>
</tr>
<tr>
<td>Near East and North Africa</td>
<td>42</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>53</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>265</td>
</tr>
<tr>
<td>Asia and the Pacific</td>
<td>642</td>
</tr>
<tr>
<td>Total</td>
<td>1.02 billion</td>
</tr>
</tbody>
</table>

Globalization also connects with processes of rapid urbanization, especially in Asia and Africa, which are fundamentally reshaping the social, political, and environmental relations through which people access food. Due to significant reductions in various forms of state support, including those stabilizing prices and protecting land tenure, and competition from imports emanating from the capital-intensive and heavily subsidized agricultural sectors of North America and Europe, many small-scale farmers have been dislocated economically, and migration to cities is an increasingly popular survival strategy. This, in turn, has contributed significantly to the rapid growth of urban areas and the urbanization of hunger throughout the developing world. The growing scale of urban food insecurity has drawn the attention of scholars and policymakers, with much of the focus on the ways in which hunger in cities differs from hunger in rural settings. For example, poor urban dwellers generally have fewer sources of nonmarket access to food, and therefore, they need more cash income to buy food, which is usually earned by working outside the home. This, in combination with the lack of adequate housing, places severe limits on the space and time necessary for preparing food and managing household food resources. These temporal and spatial demands are especially severe for women in their everyday lives, as they typically retain their traditional roles as homemakers and caregivers and cannot rely as much on informal safety nets (food sharing, child care, loans, and so on, based on social, often familial, connections), which tend to be weaker in urban areas due to the newness and constant churning of the poor urban populations. All this, furthermore, contributes to profound changes in diets and food practices—most important, a shift to processed and often higher-fat foods—and, thus, increases in the rates of heart disease and obesity among the urban poor.

The third causal process underlying patterns of hunger in the world consists of the shift of responsibility for hunger and famine prevention and alleviation from national-level governments to international relief agencies and humanitarian organizations and to local communities, charities, and social networks. This simultaneous global/local shift represents a “depoliticization” of hunger over the past 35 yrs. because it places responsibility in the hands of private individuals and organizations, which are ultimately less accountable to those suffering from that condition and less able to provide fundamental solutions. From Africa to North America, central governments have claimed to be addressing hunger by encouraging private sector responses. The changing political status of hunger—from a violation of a person’s rights to a project for charity—does not mean that charities and humanitarian organizations have not contributed in many practical ways to the alleviation of hungry people’s suffering, nor does it suggest that hungry people are docile, passive subjects who do little more than await the next act of kindness. Indeed, the latter impression is soundly contradicted by the recent spate of protests against governments around the world, from Haiti to Egypt to Malaysia, which arose as a response to rising food prices and failed state policies.

Andy Walter

See also Agrofoods; Famine, Geography of; Food, Geography of; Food and Agriculture Organization (FAO); Poverty

Further Readings

Hunting and Gathering

For the vast, overwhelming majority of time in which human beings have existed—97% to 99% of the period since the first hominids
appeared—they lived in a type of society commonly known as hunting and gathering. Many species of the genuses *Australopithecus* and *Homo* practiced this form of survival, which also typified the lifestyle, social organization, and culture of *Homo sapiens* until relatively recently—that is, until the emergence of agriculture roughly 10,000 years ago. Thus, hunting and gathering is often equated with the Paleolithic, or “Old Stone Age,” which ended with the Neolithic, or “New Stone Age” (some include a Mesolithic as well), although these terms are not universally accepted. Moreover, the line between agricultural and hunting and gathering societies is not always clear, as many societies relied on both as necessary.

Prior to agriculture, humans obtained sustenance through several modalities, including fishing, the hunting of animals, and the gathering of a wide variety of foodstuffs. Reliant on the sources made possible by their immediate environment, small groups of people, often as few as a dozen and rarely more than 50, wandered nomadically, following the seasonal rhythms of plants and migratory cycles of animals. This constant movement has led some to call hunting and gathering a “permanent camping trip.” Hunting and gathering thus made human beings food collectors, not producers. Stone and bone tools such as knives, adzes, needles, and scraping implements were the norm in cultures that lacked metal. Typically, such small bands and tribes are characterized by a sexual division of labor, in which men and boys hunt—often unsuccessfully—and women gather, often with babies on their backs or small children nearby.

Although Paleolithic hunters could be very skilled, and may have played a critical role in the extinction of numerous Pleistocene megafauna, the actual slaughter of very large animals such as mammoths was typically rather rare; smaller game such as deer and rabbits were much more common food sources. Hunting with spears and arrows was the norm, with slings and knives used when possible. The domestication of the dog, perhaps as early as 50,000 BC, also played a role that enabled hunting. More important as a source of caloric intake was gathering, the work of women, which provided the vast bulk of nutrients in most hunting-and-gathering societies. Because humans are opportunistic, adaptable improvisers, gathering allowed an exceptionally diverse variety of foods to be collected, including roots, fruits, berries, tubers, insects, carrion, eggs, grubs, frogs, seeds, nuts, and slow animals such as snails or turtles. This form of resource exploitation thus depended on lightly using a wide variety of resources rather than intensively using a few. Because it does not generate large quantities of calories per unit area, population densities remained very low. Numerous variations in hunting and gathering existed in different local climates and ecologies.

Several innovations allowed hunter and gatherers to spread to almost every ecological niche in the world. The controlled use of fire, as well as the needle and thread, enabled people to move into northerly latitudes and withstand the harsh winters of Northern Eurasia, eventually migrating into North America via the Bering Straits. Fire played a key role in the Paleolithic modification of many habitats, especially the midlatitude grasslands and forests. Rather than passively respond to their environment, therefore, hunter-gatherers actively shaped it.

Most people lived in small, self-sufficient bands, although the existence of very early trade networks in obsidian, amber, flint, seashells, feathers, and other goods indicates that some long-distance exchanges did occur. Unlike agricultural societies, in which most people spend the bulk of their time laboring, many hunter-gatherers had ample free time to relax; indeed, many people may have more free time than they do today. Organized warfare existed occasionally but was relatively uncommon, infrequent, and generally small scale and highly ritualistic.

Although they are technologically simple compared with contemporary societies, hunting-and-gathering cultures were not necessarily culturally simple. Without a complex division of labor, most such cultures were relatively egalitarian, with no classes or private property and leadership confined to a chieftain. Simple survival necessitated an intimate knowledge of nature, including the ability to identify countless species of plants and animals, to understand their behavior, to identify and use medicinal plants and herbs, or to find water in arid environments. From observations of contemporary hunters and gatherers, which form much of the basis of knowledge about them, religious beliefs were predominantly animistic or
nature worshipping. Without writing, memory formed the basis of historical and institutional consciousness, typically in the form of numerous oral folk songs, legends, and myths as told by griots, shamans, or storytellers and their counterparts. Because it was overwhelmingly verbal and aural in nature, almost all Paleolithic art has disappeared today. Pigments, jewelry, elaborate arrowheads, spearheads, and fishhooks all point to the existence of a sense of aesthetics. The existence of cave paintings in places such as Lascaux and Altamira testify to the use of symbols and abstract thought. Some observers note that the widespread dispersal of stone carvings such as the famous Earth Mother of Willendorf (25,000 BC) may indicate a high regard for women, and even matrilineal lines of descent.

In such societies, both birth rates and death rates are high; most people would begin sexual reproduction in their early teens, and average life expectancy rarely exceeded 30 years. Extended families and kinship ties formed the critical bases of local social organization and support networks. Because both birth and death rates were high, population growth rates were generally very low; some tribes practiced deliberate attempts to minimize growth through prolonged lactation or infanticide.

This form of lifestyle, which was critically important to the prehistory of human beings, was gradually annihilated beginning with the emergence of dense, agricultural societies with complex divisions of labor at the start of the Neolithic revolution around 10,000 BC. The rise of the
nation-state actively discouraged nomadism. Today, hunting and gathering is almost extinct. Small pockets can still be found among some South American tribes in the greater Amazon forest, in parts of Central Africa, among the San or !Kung people in Namibia, in parts of southeast Asia, in New Guinea, and perhaps among a few Australian Aborigines. But everywhere, hunting and gathering is a dying form of subsistence, as its last practitioners are drawn into urbanized regions and commodified labor markets.

Barney Warf

See also Centers of Domestication; Domestication of Animals; Domestication of Plants; Nomadism

Further Readings


HUNTINGTON, ELLSWORTH

(1876–1947)

The American geographer Ellsworth Huntington is most remembered for his explorations of Palestine, the Middle East, and Central Asia and the 28 books and more than 240 articles that chronicled these expeditions. The ideas and theories he derived from these researches can be broadly categorized as “geodeterministic” in that he stressed the impacts of physical, climatic factors on the development of “racial” characteristics, heredity, and civilizations. Perhaps unsurprisingly, Huntington was also president of the American Eugenics Society from 1934 to 1938. His theories have since been discredited as ethnocentric and racist, since they asserted that people from the temperate latitudes (especially the northeastern United States) were better endowed for progress than those living in tropical climates. His impact as an educator and promoter of geography as a discipline, however, should not be understated. In addition, unlike many of his contemporaries, his theories were largely based on personal experience and observation rather than on secondhand accounts.

Born in Galenburg, Illinois, Huntington’s education in geography began at Beloit College under the mentorship of Professor William Morris Davis. His professional career began in 1897 with a 4-year stint as an instructor at Euphrates College in Turkey, during which he published his first paper on the Upper Euphrates in 1902, after spending a year exploring the local canyons. His teaching gradually gave way to exploration thereafter, and during the height of the “Great Game” from 1903 to 1906, he spent much of his time exploring Central Asia on behalf of the Carnegie Institution and the American Association of Geographers. During this period, his observation that vast areas of presently arid land had once been inhabited led to his interest in the role climate change played in human demography and development and his theory that there had been large-scale changes in climate throughout history.

On his return, he took up a teaching position as an instructor at Yale University in 1907, which led to the publication of his first major books, The Pulse of Asia and Explorations in Turkestan. In these, he outlined his theories regarding the centrality of physical factors in the social and intellectual development of peoples and asserted that migrations by the Manchus and the Mongols were prompted by climatic changes rather than specific, contingent historical developments. Huntington’s teaching was again interrupted by a 1909
expedition, this time to Palestine, and from 1910 to 1913 by a series of expeditions through the United States, Mexico, and Central America as a researcher with the Carnegie Institute. After these travels, Huntington settled into a position as research associate at Yale. He continued his work in cultural geography there and published *The Climatic Factor* in 1914, *Civilization and Climate* in 1915, *The Character of Races* in 1924, *The Human Habitat* in 1927, *The Principles of Human Geography* (with S. Cushing in 1940)—and perhaps his most influential work—*Mainsprings of Civilization* in 1945, the year in which he retired.

*Edward Rice*

**See also** Environmental Determinism; Human Geography, History of; Semple, Ellen Churchill

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**Further Readings**


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**Hurricane Katrina**

The 2005 Atlantic hurricane season broke several records, including the most named tropical storms in a single year, totaling 27 (the average is 10), and the most hurricanes, 15 (the average is 5); and 7 of these were rated intense, or greater than Category 3 (the average is 2—i.e., sustained winds above 111 mi./hr. [miles per hour], or 179 km/hr. [kilometers per hour]). The 2005 season was the only time two Category 5 storms were in the Gulf of Mexico (Katrina and Rita) and the first time three Category 3 or more hurricanes made U.S. landfall in subsequent years (2004 and 2005). Hurricane Katrina was the costliest storm in U.S. history, at an estimated $105 billion. The 2005 season experienced the greatest damage total in 1 yr. (year), estimated at $150 billion (2008 dollars).

**Storm History**

Katrina began as a slow-moving easterly wave of low pressure in the trade wind belt near the west coast of Africa. The mass of rain clouds traveled across the Atlantic Ocean, becoming Tropical Depression 12 on August 23, 2005. The system intensified overnight to Tropical Storm Katrina (39 mi./hr., or 63 km/hr.) east of the Bahamas. Rapid strengthening followed as the system passed over 82 °F (28 °C) water. These storms feed on the latent heat of condensation, and warmer water provides more energy for the storm.

Hurricane warnings were posted along the Southern Florida coast. On August 25, Katrina reached 74 mi./hr. (119 km/hr.) and Category 1 status on the Saffir–Simpson Hurricane Damage Potential Scale. At 5 p.m., Katrina made landfall near North Miami Beach with sustained winds of 80 mi./hr. (128 km/hr.), causing flooding and damage and taking 14 human lives. By morning, Katrina had reached the Gulf of Mexico and moved westward over the warm water of the Loop Current. Sea surface temperatures reached 92 °F (33 °C), feeding rapid intensification.

By August 27, the system shifted course to the northwest and then north, provoking warnings for the Gulf Coast from Western Florida to Louisiana. Category 5 status was achieved on August 28, when winds crossed the 155-mi./hr. (250 km/hr.) mark, only to increase to 175 mi./hr. (280 km/hr.), with a central pressure of 902 mb (millibars) (26.61 in./hg [inches per hectogram]) later that day; normal sea-level pressure is 1,013.2 mb.

The governor of Louisiana declared a state of emergency for her state on August 26, followed by President George W. Bush’s major disaster declaration on the afternoon of August 28. Evacuation efforts were underway by the morning of August 28. Estimates place the number of people who were evacuated at nearly 1 million, with 374,000 of these listed at shelters in other states. The critical problem was that 120,000 residents of the New Orleans area did not have
personal automobiles and had to rely on public transportation.

A buoy 50 mi. southeast from the mouth of the Mississippi River measured a wave height of 55 feet (16.8 meters) on the morning of August 29—a record for the National Data Buoy Center. Landfall occurred at 6:10 a.m. CDT (central daylight time) in Plaquemines Parish between the Mississippi River mouth and Grand Isle. Katrina slowed to a Category 3 with sustained winds up to 130 mi./hr. (210 km/hr.). By 8:00 a.m., Katrina was 40 mi. southeast of New Orleans, shifting slightly to the east; then, by 10:00 a.m., it made a second landfall along the Louisiana-Mississippi border. The lethal front-right quadrant of the storm was hitting the Mississippi Gulf Coast, while easterly winds north of the eye wall were pushing the waters of Lake Pontchartrain into New Orleans. The storm surge and winds obliterated many towns, with the damage extending east into coastal Alabama. Sixty oil spills, totaling 4 million gallons, occurred as facilities along the coast broke and more than 100 oil-drilling platforms were destroyed.

As happens with these latent heat engines, Katrina started to weaken as it moved inland, though it was still a powerful rainfall event. By 7 p.m., on the day of landfall, it was about 30 mi. north of Meridian, Mississippi, with winds below 74 mi./hr. (119 km/hr.)—it was now Tropical Storm Katrina. By the time it reached Tennessee on August 30, Katrina dropped to a tropical depression. On August 31, it became an extratropical depression as it crossed the Great Lakes into Canada.

In the days following landfall, the nation watched the grim story unfold on television. Twenty-five thousand people were stranded at the Louisiana Superdome and another 20,000 at the convention center in New Orleans with little food, water, or any sanitation facilities—24 people died at the center. Tragically, four hospitals with intensive care patients were likewise stranded without electricity or supplies for days after landfall. Many days passed as the federal government and its Federal Emergency Management Administration (FEMA) delayed their response for as yet unexplained reasons. The head of FEMA was removed from office on September 9, but the slow response continued. Eventually, 1.2 million people underwent some form of evacuation.

### Engineering Failures in New Orleans

Katrina nearly obliterated the sandy barrier islands that lay offshore. Under normal circumstances, these islands serve to protect the Mississippi River delta from wave action. The Chandeleur Islands, 19 to 25 mi. (30–40 km) from the Louisiana-Mississippi Gulf Coast, lost half their sand inventory due to Hurricane Georges (1988). More sand losses followed from Hurricanes Lili (2002), Ivan (2004), and Dennis (2005). However, Katrina basically wiped out the islands, leaving about 10% of the former sand volume.

The city of New Orleans is almost entirely below the elevation of the Mississippi River, with sections of the city below sea level. Severe flooding is a certainty for existing and planned settlements. The events of 2005, following the passage of Hurricane Katrina, will remain for many years as one of the greatest engineering failures by the government and the U.S. Army Corps of Engineers. Fully 80% of New Orleans was under water. Four levee breaks and at least 50 levee breaches (topping) led to the inundation of a major city.

More than 4 yrs. after the disaster, much of the debris of lost neighborhoods still remains. Six investigations by civil engineers, scientists, and political bodies agreed that the design, construction, and maintenance of the “protection” system were flawed. Many structures failed before they reached the design failure limits. After all, Hurricane Katrina was a Category 3 as it moved onshore. Several of the levee floodwalls were weak because they were not anchored to the correct depth, such as along the 17th Street Canal. In 2007, civil engineers inspecting the levee and floodwall repair discovered that the composition of fill materials was too low in clays and too high in sand. At the end of 2009, repair work in New Orleans was still not completed.

### Future Forecast

Research has established a “total dissipation index” to rate the potential destructiveness of tropical cyclones over their lifetime. The MIT (Massachusetts Institute of Technology) scientist
Kerry Emanuel defined an “index of potential destructiveness” and found that the intensity of tropical storms and hurricanes had increased markedly since the 1970s. Storms have been lasting longer, with increased intensity. Emanuel determined strong correlations between tropical sea surface temperatures and the doubling of power of storms.

Another research team, headed by Carlos Hoyos, Georgia Institute of Technology, completed work in 2006 and found that the increasing numbers of Categories 4 and 5 hurricanes since 1970 were directly linked to increasing sea surface temperatures. These increases in temperature were the only statistically significant variables explaining the intensification of global hurricane strength.

Given the climate change now underway, the forecast is for further intensification.

Researchers suggest that global climate change, when considered alongside increased coastal population settlement and rising sea levels of more than 0.4 in. (1 centimeter) per year along the Gulf Coast, will produce substantial future hurricane-related losses. Warmer seas provide more energy, and warmer air absorbs more water vapor, with all this energy converted into tropical cyclone winds. Researchers identified the key role of higher ocean and air temperatures. The forecast for vulnerable coastal regions is not positive.

Robert W. Christopherson
Labeled a typhoon in the Pacific Ocean west of the International Dateline and a cyclone over the Bay of Bengal and Arabian Sea, a hurricane is powered by the heat and moisture of the tropics rather than temperature differences across latitudes, as is the case for the more common extratropical cyclone. This entry describes the characteristics and classification of hurricanes, the types of damage they can cause, and current research on hurricane activity.

A hurricane begins as an area of low air pressure over warm ocean waters (at least 27 °C down to 50 m [meters] below the sea surface). As a result of atmospheric instability, the area of low pressure features numerous showers and thunderstorms that, over several days, organize the winds into a counterclockwise (clockwise in the Southern Hemisphere) swirl. The swirl in turn helps new thunderstorms develop. The swirl becomes a tropical storm when the circulating wind speeds, estimated at 10 m above the ocean, exceed 17 m/s (meters per second), averaged over 1 minute.

When the wind speeds reach 33 m/s or more, the tropical storm is called a hurricane. Once formed, the hurricane winds are maintained by the import of heat from the ocean at high temperatures and the export of heat at lower temperatures in the upper troposphere (close to 16 kilometers above sea level at the equator), similar to the way a steam engine converts thermal energy into mechanical motion.

**Hurricane Winds**

Strong winds are the defining characteristic of a hurricane. Wind is caused by the change in air pressure from one location to another. In the eye of a hurricane, the air pressure, which is the weight of a column of air from the surface of the Earth to the top of the atmosphere, is quite low compared with the air pressure outside the hurricane. This pressure difference causes the air to move inward, toward the center of the hurricane.

By a combination of friction, as the air rubs on the ocean below, and the spin of the Earth, as it rotates on its axis, the air spirals inward in a counterclockwise direction toward the region of lowest pressure. The vertical component of the Earth’s spin is too weak to support a spiral within about 5° of latitude from the equator, so hurricanes do not develop close to the equator.

To a first approximation, the pressure difference between the eye and the air outside the hurricane determines the speed of the wind. Since the pressure outside the hurricane is roughly uniform, a hurricane’s central pressure is another measure of a hurricane’s intensity. The lower the central pressure, the more intense is the hurricane. Pressures inside the most intense hurricanes are among the lowest that occur anywhere on the Earth’s surface at sea level.

Hurricanes vary widely in intensity, as measured by their fastest-moving winds. Hurricane intensities are grouped into five categories (Saffir-Simpson scale), with the weakest, Category 1, winds blowing at most 42 m/s and the strongest, Category 5, winds exceeding speeds of 69 m/s.

Hurricanes also vary considerably in size (spatial extent), with the smallest hurricanes measuring only a few hundred kilometers in radius (measured from the eye center to the outermost closed line of constant surface pressure) and the largest exceeding a thousand kilometers or more.

In the largest and most intense hurricanes (e.g., Hurricane Katrina in 2005), the strongest winds are located in the eye wall that surrounds the nearly calm eye. The distance from the center of the hurricane to the location where the winds are blowing the strongest is called the radius of maximum winds. In a well-developed hurricane, the radius of maximum winds is found at the inner edge of the eye wall. This distance varies considerably from hurricane to hurricane though, and due to cycles of eye wall replacement, even from day to day for a particular hurricane. While the wind just above the ocean surface spirals anticlockwise toward the center, the air at high altitudes blows outward in a clockwise spiral. This outward-flowing air produces thin cirrus (feathery) clouds that extend to great distances (thousands of kilometers) from the center of the hurricane. The presence of these clouds may be the first sign that a hurricane is approaching.

Hurricanes are steered by large-scale wind streams in the atmosphere and by the increasing component of the Earth’s spin away from the equator. In the deep tropics, these forces push a hurricane slightly north of due west (in the Northern Hemisphere). Once north of about 23° of latitude, a hurricane tends to take a more northwestward track, moving eventually northeastward at still higher latitudes. This creates the parabola-shaped track often reproduced on

Pictured from space, Hurricane Frances lashes the Bahamas Islands on September 3, 2004.

Source: National Oceanic and Atmospheric Administration.
Hurricanes, Physical Geography of

Maps of historical hurricanes. Local fluctuations in the magnitude and direction of steering can result in tracks that deviate significantly from this pattern.

Landfall occurs when the hurricane center crosses a coastline. Because the fastest winds are located in the eye wall, it is possible for a hurricane’s fastest winds to be over land even if landfall does not occur. Similarly, it is possible for a hurricane to make landfall and have its fastest winds remain out at sea. Fortunately, the ferocious winds slacken quickly after the hurricane moves over land. Hurricanes made landfall in the United States at an average rate of five every 3 years during the 20th century.

Hurricane Damage

Winds blowing overland from a hurricane destroy poorly constructed buildings and mobile homes. Debris such as signs, roofing material, and small items left outside become flying projectiles, adding to the destructive power of the wind.

Besides the destructive power of the winds, hurricane damage results from two other causes: flooding from torrential rains and storm surge. Rainfall is the quantity of water, expressed in millimeters, that falls from the hurricane in a specified area over a given time interval. Hurricanes derive energy from the ocean by evaporating the water into the air, which then gets converted back to liquid water through condensation inside thunderstorm clouds. The water falls from the clouds as rain, and the stronger the hurricane thunderstorms, the greater the amount of rain and thus the greater the potential for flooding.

The amount of rain deposited over land from a hurricane depends on many complex factors, including hurricane intensity, forward speed, and the underlying topography. The rainfall of a hurricane can intensify when the strong winds carry the moisture up a mountainside. The saturation condition of the soil from previous rains also plays a role in whether and to what extent flooding will occur. Freshwater flooding from torrential hurricane rainfall can be a serious danger hundreds of kilometers from the point of landfall.

Bands of showers and thunderstorms that spiral inward toward the hurricane center are the first sensible weather experienced as a hurricane approaches. High-wind gusts and heavy downpours occur in the individual rain bands, with relatively calm weather occurring between the bands. A brief tornado may form in a rain band, especially as the hurricane crosses the coastline.

Storm surge is ocean water that is pushed toward the shore by the force of the winds moving around the storm. Over the open ocean, the water can flow in all directions (including downward) away from the storm. Strong winds blowing across the ocean surface create a stress that forces the water levels to increase downwind and decrease upwind. This wind setup is inversely proportional to ocean depth, so over the deep ocean away from land, the water level rises are minimal. However, when the hurricane approaches shallow water, there is no room for the water to flow underneath, so it rises and gets pushed by the wind as a surge, much like a snowplow pushes the snow from the roadway. The advancing surge can increase the water level 5 m or more above sea level. In addition, wind-driven waves are superimposed on the storm surge. The total water level can cause severe surge impacts in coastal areas, particularly when the storm surge coincides with the normal high tide caused by the sun and the moon.

The slope of the continental shelf also determines the level of surge in a particular area. A shallow slope will allow a greater surge. With a steeper continental shelf, coastal areas will not experience as much surge inundation, although large breaking waves can still present major problems. The low pressure in the middle of the storm causes a smaller part of the storm surge.

The pressure inside the eye is much lower than the surrounding atmosphere, so the water gets lifted. This will cause the sea surface over the open ocean to rise in regions of low pressure and fall in regions of high pressure. In general, for a 1 hectopascal drop in surface pressure, there is a 1 centimeter rise in sea level. In short, the cause of storm surge is the combined effect of low air pressure and persistent winds blowing over the ocean surface.
Hurricane Tracking

Today, hurricanes are tracked with satellites, radar, and specially equipped aircraft on reconnaissance flights. Ocean buoys and ships also provide storm information. Successful experiments with remotely piloted drone aircraft (aerosonde) suggest that they might be used to help forecast the intensity and track of hurricanes in the near future.

Because of their potential for death and destruction, the U.S. National Hurricane Center issues watches and warnings for hurricanes threatening the United States a few days before a potential landfall. A hurricane watch means that hurricane conditions in specific coastal areas are possible within 36 hrs. (hours). A hurricane warning means that hurricane winds associated with a hurricane are expected in a specified coastal area within 24 hrs. A hurricane warning can remain in effect when dangerously high water or a combination of dangerously high water and exceptionally high waves continues, even though the wind may be less than hurricane intensity.

Global Hurricane Activity

On average, 50 hurricanes occur worldwide each year. Hurricanes develop during the time of year when the ocean temperatures are hottest. Over the North Atlantic (including the Gulf of Mexico and the Caribbean Sea), this includes the months of June through November, with a sharp peak from late August through the middle of September. The time difference between the peak in solar radiation receipt in June (Northern Hemisphere) and the peak in hurricane activity is due to the fact that the terrestrial (oceanic) long-wave radiation emission lags solar radiation by a few months. Worldwide, May is the least active month for hurricanes, while September is the most active.

Hurricane activity, on time scales of seasons and longer, responds to variations in climate. To a first order, greater ocean warmth and relatively calm winds enhance the potential for hurricanes. For instance, in the western tropical North Atlantic and Caribbean Sea, deep warm water and low values of upper atmospheric wind shear create conditions favorable to initiate and sustain hurricanes before they strike the United States. The strength and position of the subtropical high-pressure zone determine the steering currents, which is important for predicting landfall probabilities. Catastrophe models that project future damage losses from hurricanes now include this information.

Increases in ocean temperature will raise a hurricane’s potential intensity, other things being equal. However, corresponding increases in atmospheric wind shear—in which winds at different altitudes blow in different directions and tear apart the developing hurricane—could counter this tendency by dispersing the hurricane’s heat. A recent study based on a set of homogenized satellite-derived wind speeds indicates that the strongest hurricanes are getting stronger worldwide. Modeling studies indicate that rainfall from hurricanes may get heavier in the future. However, more research is needed to better understand these important issues.

James B. Elsner

See also Air Masses; Atmospheric Energy Transfer; Atmospheric Pressure; Climate Change; Coastal Hazards; Floods; Hurricane Katrina; Hurricanes, Risk and Hazard; Oceans; Thunderstorms; Wind

Further Readings


Hurricanes, Risk and Hazard

Throughout history, hurricanes have been the leading cause of deaths associated with short-term natural hazards. Populations along coastal areas are exposed to a number of hurricane-related hazards, including, but not limited to, storm surge, high-speed winds, heavy rainfall, flooding, and tornadoes. This entry explores the geography
of hurricane risk in the United States and provides an overview of hazards associated with hurricane events.

Geography of Risk

An average of two hurricanes reaches the coast of the United States each year. In the United States, hurricanes most frequently make landfall along the shores of Eastern Florida, Georgia, South Carolina, and North Carolina; however, coastlines along the Gulf of Mexico as well as the Atlantic coast from Virginia to Maine are also at risk. Hurricanes often span hundreds of miles in width and thus are capable of causing widespread damage to inland areas. Most of the substantial damage and loss of life attributed to hurricane hazards transpires within 60 to 100 mi. (miles) of where the storm makes landfall.

Population growth along the coastal areas has increased the number of Americans at risk from hurricane hazards. The U.S. Census Bureau estimated that in 2007, more than 35 million Americans along the coastline from North Carolina to Texas were at high risk from hurricane-related threats. In addition, the locations most vulnerable to hurricane events experienced 247% population growth since the 1950s. Despite the increasing coastal population, hurricane-related deaths have dramatically decreased throughout the past century due in part to better warning systems. However, economic losses resulting from hurricane hazards have greatly increased because of rising property values, new construction, and increased industrialization in coastal areas.

Hurricane Hazards

Hazards attributed to hurricane events vary greatly in magnitude, geographic extent, and the resulting damage. The hazards that result in the most damage to coastal areas during a hurricane include storm surge, high-speed winds, heavy rainfall, flooding, and tornadoes. These hazards are described in further detail below.

Historically, the storm surge has been responsible for the majority of hurricane-related deaths. The storm surge is a hurricane tide that is primarily driven by strong winds. Storm surges can raise local ocean water levels by more than 20 ft. (feet) and can extend along a coastline for more than 100 mi. Much of the damage caused by a storm surge is limited to locations near the coastline. Debris carried by these waves contributes to their destructive force, causing significant damage to buildings and property located in low-lying areas. The most devastating storm surge in U.S. history occurred during the Galveston Hurricane of 1900, where an estimated 8,000 to 12,000 people on Galveston Island, Texas, were killed when a 15- to 18-ft. storm surge inundated the island.

High-speed winds are another hazard related to hurricanes. Hurricane-force winds exceeding 74 mi./hr. (miles per hour) often suspend large debris into the air, causing widespread damage to homes, buildings, trees, and utility lines. Hurricane-force winds are responsible for some of the highest wind speeds ever recorded. Hurricane Celia generated sustained winds of 161 mi./hr. as it made landfall on the coast of Corpus Christi, Texas, in 1970, and Hurricane Camille, in 1969, struck the Louisiana coastline with sustained winds reported at 172 mi./hr.

Heavy rainfall and flooding pose a threat to both coastal and inland areas. On average, hurricanes produce 6 to 12 inches of rain after landfall; however, the heavy rainfall is not always confined to the coast. Inland areas are at risk of getting substantial rainfall produced by the remnants of a hurricane. Between 1970 and 1999, inland flooding accounted for more than half of all hurricane-related deaths, with most of these fatalities occurring at night while the victims were driving.

Tornadoes are also a hazard associated with hurricanes. The devastating winds produced by hurricane-spawned tornadoes compound to the destruction already caused by other hurricane-related hazards. These tornadoes frequently occur before the eye of the storm moves ashore and usually develop in the front right quadrant of the hurricane’s track. Studies conducted on tornadic activity during hurricanes indicate that almost 60% of all hurricanes that hit the United States between 1948 and 1986 generated at least one tornado. However, the number of tornadoes hurricanes produce
HURRICANES, RISK AND HAZARD

varies. For example, in 2004, six tropical storms that struck the United States produced more than 300 tornadoes. Tornadic activity during hurricanes also varies geographically. Areas along the coastlines of Texas and Louisiana and the west coast of Florida are almost twice as likely to experience tornadoes during a hurricane event as areas located along the North Atlantic coastline.

**Protective Measures**

Substantial progress has been made in reducing the number of fatalities associated with hurricanes. Improved forecasting techniques have assisted in the issuance of more accurate hurricane watches and warnings. The establishment of better warning systems has led to more effective communication of hurricane threats to communities. In addition, the implementation of evacuation strategies has greatly reduced the number of hurricane-related deaths. However, numerous challenges still exist in mitigating economic and property losses during hurricane events. Failure by local and state governments to evaluate hurricane risks as well as make mitigation efforts a priority in their communities greatly increases the losses associated with hurricanes. As demonstrated during Hurricane Katrina in 2005, lack of preparedness before, during, and after a hurricane event can have devastating consequences on a community. Improved management of hurricane events, as well as the implementation of better mitigation strategies along the coastline, can greatly reduce the losses related to hurricane hazards.

*Laura Kathryn Siebeneck*
HYBRID GEOGRAPHIES

Geography has long been characterized as an integrative field—a hybrid discipline that combines elements of the natural and social sciences. With contributions from the humanities and social theory, more explicit considerations of hybrid geographies have attracted increasing critical attention. This trend represents both a new set of concepts in response to new technologies and conditions as well as a renewed embrace of one of the oldest ideas in geography—that simultaneous inquiry of social and natural elements can provide important insights.

At their most basic, hybrid geographies are places, organisms, or other entities that cannot or should not be readily characterized by any single category. As the term hybrid denotes, these places or things feature elements from multiple origins to the extent that they can only properly be considered as new and often rather fluid kinds. In this respect, the study of hybrid geographies represents an effort to depart from common dualisms found in geography and other fields.

In fact, hybrid geographies signify new kinds of places or entities, new ontologies, as well as new ways of generating knowledge to conceptualize these new kinds. This epistemological turn presents something of a conundrum: In its deepest form, the study of hybrid geographies calls for the obliteration of prior categories such as nature/society, local/global, inside/outside, or natural/artifactual to instead recognize associations, networks, or mixed qualities that resist traditional dualisms. While this effort to find alternative frameworks appeals to geographers who oppose labels such as “physical” or “human” to delimit their field’s principal perspectives, a determined effort to defy categorization can also lead to problems of linguistic or conceptual clarity. Hybrid geographies therefore can seem rather elusive or even provide ironic reminders that categories and dualisms are often created for the very practical purpose of simplifying complex ideas.

Describing places as hybrid geographies is, at least initially, the most obvious and intuitive aspect of a much broader project. Relating to critical studies of landscape, a number of scholars emphasize that cities, farmlands, wildlife refuges, and even wilderness areas are not only natural or social spaces but that these can all be considered sites of synthesis where human and nonhuman agency conspire and coalesce. In this view, landscapes are not merely an array of physical objects but rather dynamic places built through social activities, economies, and values as well as environmental conditions.

This integration across potentially disparate categories may be very apparent or quite subtle, but in either case, such blending can be seen as a form of hybridization. Cities may seem at a glance to consist purely of human elements: asphalt and concrete, glass, steel, and mechanization; but a closer look, inevitably, also reveals nonhuman elements such as terrain, watercourses, plants, wildlife, or weather. Similarly, on careful inspection, “natural” places such as wildlife refuges or wilderness areas reveal complex generative histories of human use, management, regulation, and mapping.

If pursued vigorously, this integrative consideration of landscapes can be extended to virtually any setting to make a case for hybridity. After all, with advances in technology, we can

Further Readings

now detect industrial residues in the most remote icefields on the planet and synthetic chemicals in the cord blood of newborn babies. In the face of retreating glaciers or the early onset of puberty in children, it may be only appropriate to reconsider these and many other disparate contexts as hybrid geographies of inseparable natural and social production.

This idea leads us to rethink how we describe or come to understand the world fundamentally. Rather than thinking in terms of set categories—of nature and society, for example—an epistemological shift toward hybridity recasts the framework to emphasize relationships. Scholars promoting concepts of hybridity label it somewhat differently: Jonathan Murdoch presents it as “associationalism,” Sarah Whatmore calls it “commotion,” and Bruno Latour orients it by means of networks, but in each case, the effect is to blur the distinctions between categories and emphasize connectivity. Such a project effectively diminishes the role of essential or “pure” qualities in a place or entity and instead highlights the dynamic qualities that destabilize traditional ontologies. To return to one of the examples above, a Greenland icefield is no longer the exclusive result of natural climate and precipitation, but instead it is a shifting (and currently diminishing) product of these processes, inseparably conjoined with emissions from coal-fired power plants and automobiles and a global trend toward industrial development.

This type of reformulation understandably makes many people uneasy. Hybrid geographies challenge long-held views of what we think we know about the world. In this respect, the study of hybrid geographies can bring a radical philosophy to geographical inquiry in ways that remain to be fully explored. At the basic level of communicating ideas, how do we describe places or organisms if we are committed to turning away from dualistic categories? Bruno Latour seeks to blur the distinction between set categories with actor-network theory, which highlights the relationships among natural, social, and technological systems. This networked approach informs much of the geographical work on hybridity and has gained considerable popular relevance with the advent of the Internet and social networking Web sites.

Broader changes in technology and land use have, in fact, spurred a good deal of activity in the study of hybrid geographies in recent years. This has occurred across a variety of scales and contexts, from the scientific manipulation of particular organisms to the reclassification of entire landscapes. Two cases, the production of genetically modified organisms (GMOs) and the conversion of closed military bases, provide useful examples to consider the range of conditions and processes hybrid geographies can encompass.

**Genetically Modified Organisms**

Hybridization attracts public notice most often in the context of cross-fertilizing plants or animals, with the subsequent organism often exhibiting characteristics that blend the features of the originals. While such hybrids initially occurred without human intervention, plant and animal breeders quickly recognized that certain traits in offspring could be emphasized if disparate species or varieties were intentionally selected and combined. What began as the deliberate, relatively simple process of mixing parental stock repeatedly until the desirable qualities emerged has, with technological advances, become in some cases a much more directed process of selecting particular qualities from disparate origins and blending genetic material to create GMOs or transgenic organisms.

This relatively recent ability to infiltrate the genetic stock of organisms has vastly expanded the array and kinds of hybrids now extant. Entire landscapes can be filled with organisms that never could have been formed without active intervention and manipulation by human technicians. Such hybrid geographies have gained the most acclaim and notoriety in the context of agriculture, including products such as “golden” rice and oranges loaded with omega-3 fatty acids. Golden rice was developed by incorporating unrelated genetic material from daffodils and a soil bacterium into the endosperm of rice to boost levels of beta-carotene and vitamin A. Differing markedly in appearance and nutritional content from unmodified rice, golden rice can be grown and consumed much like any other plant, but its high-tech origins nudge it out of the standard categories of “natural” foodstuffs. At a basic level, it
is clearly the blended product of human intervention and long-standing environmental processes.

Oranges with enhanced levels of omega-3 fatty acids were similarly developed with the goal of improving the nutritional capacities of a common food, but in this case, the genetic modification reaches across a more striking gap. Omega-3 oranges rely not just on plant-to-plant transfer but also on the manipulation of genetic material from anchovies into commercially grown citrus fruit. Few consumers of the resulting orange juice are likely even aware that they are ingesting the crossed product of a fruit-fish hybrid, a point that highlights the sometimes invisible qualities of hybrid geographies.

Moving to a rather different scale and context, we can also find hybrid geographies in a number of sites formerly managed exclusively for military production and now undergoing conversion to a more diverse array of land uses. For example, nearly two dozen former military installations in the United States have recently been converted and reclassified as national wildlife refuges.

Through a mix of natural, social, and technological processes, these conversion sites develop into altogether new geographies that retain qualities from multiple categories. Many of these sites contain unexploded ordnance, chemically contaminated soils and waters, ammunition bunkers, missile storage igloos, airport runways, or other remnants of military production while also exhibiting characteristics associated with the conservation mission of the U.S. National Wildlife Refuge System, such as habitat for imperiled plants and animals. In this way, these military-to-wildlife conversion sites no longer fit neatly into categories of spaces of either/only militarism or wildlife conservation but instead call for a more diffuse notion of multiplicity and coproduction. In other words, they may be much more aptly considered as hybrid spaces or hybrid geographies. What may have once been tempting to consider as an artificial array of military bases is, in these cases, blending increasingly with what was once formerly seen as a natural system of wildlife refuges.

As highlighted above, the study of hybrid geographies not only focuses on these sorts of places and organisms that defy easy categorization but also seeks to challenge the earlier assumptions that allowed categories such as natural and artifactual to withstand critical scrutiny. In both respects, hybrid geographies represent efforts to enhance geography’s critical engagement with the world and to seek meaning in ways that challenge existing disciplinary assumptions.

David Havlick

See also Actor-Network Theory; Critical Human Geography; Nature-Society Theory; Poststructuralism; Social Construction of Nature

Further Readings


HYBRIDIZATION OF PLANT AND ANIMAL SPECIES

Hybridization is a fundamental evolutionary process that can lead to further differentiation by the creation of unique individuals or new evolutionarily significant units that eventually may become new species. However, hybridization can also create significant barriers on the path to diversification by allowing gene flow between two related yet distinct individuals or populations that will decrease the differentiation between them. Charles Darwin devoted Chapter 9 of The Origin of
Species to the discussion of hybridization and the outcomes that result from two distinct species or populations reproducing to create unique offspring—whether viable or sterile. The processes of hybridization as well as the offspring that are generated through this method are of great importance to biogeographers and other natural and physical scientists who are investigating speciation or loss of diversity in specific assemblages. Additionally, hybridization is a significant phenomenon when discussing the modern breeding of domestic animals and plants.

Types of Hybrids

Hybrids are those individuals that have been produced through the reproductive crossing of two parents from distinct taxonomic groups. Hybrids that result from the crossing of two separate species are generally referred to as interspecific hybrids. Typically, interspecific hybrids have nonviable or sterile offspring, which is the criterion used to distinguish taxonomic groups as separate or belonging to distinct species. The biological species concept is based on this observation that two distinct species cannot produce viable offspring. However, there are always exceptions to this rule, and often, viable offspring are produced through these crosses, whether random or intentional.

When two individuals from the same species group, but from different subspecies, cross, their offspring are referred to as intraspecific hybrids. These intraspecific crosses can also occur between distinct populations, cultivars, and specific breeds within a single species or the primary gene pool for a taxonomic group. This type of hybridization is particularly important in animal and plant breeding efforts that strive to incorporate characteristics from two distinct sets of parental groups that can be consistently found in offspring as a result of reproductive crossing and can confer some benefit to the offspring that is not found individually in either parent population.

On occasion, hybrids result from the crossing of individuals from different genera, referred to as intergeneric hybrids. Even rarer are hybrids above the genus level—at the family level. These offspring are known as interfamilial hybrids and are very uncommon in nature.

Examples of Hybrids

Examples of hybrids include the following:

- Domestic dogs are dogs that are bred using different breeds.
- Mules are the result of the crossing between a female horse and a male donkey.
- The zeedonk/zonkey is the result of a cross between a zebra and a donkey.
- The limequat is a lime and kumquat hybrid.
- The tangelo is a cross between different citrus subspecies.
- The triticale is a hybrid of wheat and rye.

Benefits of Hybridization

The process of hybridization between individuals from distinct evolutionary groups has had a tremendous impact on the diversity of specific ecosystems, particularly agro-ecosystems. Speciation may result from hybridization, thus increasing the amount of biodiversity found within a specific range or region. Reticulate speciation occurs between two distinct species that are part of a monophyletic group when they hybridize and create a new species; thus, having been separated at one point in evolutionary history, they come back in contact to create a new species. Heterosis, or hybrid vigor, is also a beneficial result of hybridization. Farmers for centuries have been consciously and unconsciously taking advantage of the positive outcome of crossing individuals from distinct populations or races. Intraspecific hybrids typically have a higher fitness than either parent population would have through normal reproduction within each parental group, thereby conferring this benefit to the hybrid offspring. Modern plant- and animal-breeding programs have taken advantage of the granted benefits of heterosis by creating advanced cultivars that are extremely fit under certain conditions. For example, conventionally produced corn (or maize) is the product of hybridization to capture hybrid vigor in each generation. Additionally, domestic dogs that are the result of hybridization between more than one distinct breed often outlive and have less health problems than their purebred counterparts.
Limitations of Hybridization

Just as the process of hybridization can bestow benefits to the populations and offspring affected by this evolutionary process, there are also several limitations to the phenomenon. Many of the resulting offspring have serious health and genetic limitations because of the resulting admixture of chromosomes from distinct parental populations. Many of these offspring have deleterious characteristics and do not live for more than a few hours or days after birth. Typically, hybrids between different species and higher taxonomic groups are not reproductively viable because of chromosome problems or dysfunctional reproduction issues. This is more common with animal hybridization, but it can occur in plant hybrids as well.

Of particular concern when dealing with hybrid offspring is the potential for genetic erosion through introgressive hybridization, or introgression. Introgression occurs when a hybrid offspring then backcrosses with one of the parental groups. This backcrossing, or introgression, can cause a loss of allelic diversity within the parental group, thus diluting the genetic diversity of the parental population. This is very significant when investigating the domestication of agricultural plant species. Oftentimes, traditionally and conventionally bred material will hybridize in the areas of origin with the wild ancestor or progenitor of the population, causing a significant loss of diversity in the gene pool of the species. This is referred to as genetic erosion and can occur in both plant and animal populations. This type of introgressive hybridization has occurred in common beans as well as between different species of crocodile. The most devastating consequence of such a cross is that often one of the species is already threatened, and through hybridization and subsequent backcrossing with parental groups, that population suffers severe genetic erosion or pollution of its genome and, in rare cases, extinction.

Laura R. Lewis

Further Readings


Hydroelectric Power

Hydroelectricity is a derivative of hydropower, which is energy captured from river systems. Hydroelectricity is a scientific-technological system that resulted from the invention of electricity and the creation of the river water–powered turbine onto which a rotor is mounted to generate electricity. Michael Faraday (1791–1867) is credited with inventing electricity in his London laboratory in 1831. Twenty years passed before the Francis turbine was created in 1851. Hydroelectricity became a physical reality when the turbine and the rotor were effectively assembled to generate electricity at Rothbury, United Kingdom, in December 1880, and the first public electricity-supplying unit was installed at Godalming, United Kingdom, in 1881. In the United States, the earliest hydroelectric installation was placed at Appleton, Wisconsin, in 1882, and by 1889, a textile mill in Juiz de Fora, Minas Gerais, Brazil, built its own electricity source to service the mill. The diffusion of this power source coincided with the accelerating pace of industrialization in Europe and the Americas.

Hydroelectricity enlarged the energy matrix at the time, post-1880s, when the pace of industrialization increased in northwestern Europe and the northeastern United States. The demand for electricity was rooted in the illumination of public spaces such as streets, parks, and public buildings, abolishing the gas lamps. Horse-drawn
streetcars were replaced by electric trolley cars, and factories turned to dynamo-powered machinery and away from belt-driven equipment. The increased demand for electricity fostered the expansion of the installed power park, which was building local thermal electric power stations in the coal-rich states. Coal-poor states such as France, Italy, and Switzerland decided to power their growing manufacturing systems by tapping into rivers to draw on the hydroelectric potential, reducing their dependence on coal and foreign exchange transfers. All three countries developed heavy engineering industries to build the mechanical infrastructure for hydropower dams. Builders of hydroelectric projects discovered an attractive incentive in hydroelectric power stations—namely, that they provided the least costly energy.

Just as there was a notable time lag between the invention of electricity and the introduction and spread of hydroelectric dams, there was also a time lag between the setting up of the transmission system and the effective transmission of electricity to the required distance. The one-time ½-km (kilometer) power line gradually expanded to hundreds of kilometers of transmission lines, and now 3,000 km of lines exist; with the coming of superconductivity, even these limits will fall. Efficiency (measured in kilovolts) is determined by the distance the electricity is transmitted—that is, the higher the number of kilovolts, the greater is the distance that the power can be transmitted. Energy loss occurs at two levels: one in transmission (transport) and the other in stepping up or down the kilovolt value of the electricity sent. Generally, 15% of electricity is lost in the transforming process. This is mechanical, not distance based.

Hydroelectricity has been instrumental in the industrialization process in many countries. From 1920 to 1940, hydroelectricity was widely implanted as a key electricity source in Europe and had strong acceptance in the USSR from 1917 to 1990. In the United States, hydroelectricity acquired landmark status with the Hoover Dam on the Lower Colorado River. In the mid 1930s, the United States created the Tennessee Valley Authority, with a multiple hydroelectric dam system to foster regional economic development and land reclamation. The Columbia River basin became the site for numerous major dams, for example, Bonneville and Grand Coulee, serving industrialization needs such as aluminum production and uranium processing for the federal government and the electricity needs of the Pacific coast region. Many of these dams would later become a key cause of population declines in several species of salmon, by destroying important spawning and rearing habitats.

The post–World War II years became a time of economic reconstruction in much of Europe, the USSR, and East Asia. South Korea embarked on reconstruction and hydroelectric expansion after 1953. In the 1950s, the expansion of hydroelectric plant construction began in Europe and the United States; this was also a time when significant changes in the global economy and electricity demand enhanced the attractiveness of domestic hydroelectric sources. The planning and building of hydroelectric systems can take years as numerous environmental assessment studies, project cost analyses, market demand inventories, and electricity delivery systems transmission networks have to be assembled and placed in chronological order for effective implantation and service.

Expansion of the hydroelectricity sector is measurable by using the volume of total kilowatts generated. Between 1950 and 2005, the world’s total number of installed hydroelectric systems increased by 1,588%. The distribution of installed hydroelectric systems is regionally uneven and reflects the increased availability of other energy sources. It is instructive to consider electricity data from a regional perspective and in proportion (%) to the total number of installed electricity-generating systems (Figures 1 and 2).

Hydroelectricity contributes generally about 20% of the total electricity consumed worldwide. The global distribution of installed hydroelectric systems is uneven in time of construction, size, and service area. Here, technological changes contribute toward updating the equipment and providing improved transmission systems to significantly extend the reach of regions served. Globally, Asia by 2005 had become the dominant hydroelectric region, registering 34.4% of all operating hydroelectric units. Up to 64.4% of South America’s electricity needs were met by the hydroelectric sector in 2005. China’s hydroelectric sector provided 23% of the country’s electricity needs in 2005, illustrating the growing
**Figure 1** World electricity-generating capacity (in megawatts), 2005


**Figure 2** Hydroelectricity installed capacity (in megawatts) in selected states, 2005

demand for electricity there, as well as the pressure to enlarge the electricity supply systems everywhere. A prominent hydroelectricity-dependent country is Norway, as it derives up to 98% of its electricity supply from waterpower! In the same category is Paraguay. Brazil is another hydroelectric-dependent state as 76% of its electricity needs are hydro generated. Two projects in Brazil provided 33% of all the electricity consumed in the country in 2008: (1) Turcurui (Turcurui-Tocantins Rivers image), with an installed capacity of 8,340 MW (megawatts), and (2) Itaipu (Itaipu-Binacional image), at 14,000 MW.

The diffusion of hydroelectricity coincided with the expansion of industrialization from the core manufacturing regions, namely, northwestern Europe and the northeastern United States, at the end of the 19th century. In the United States, the 1930s was an era when large mega-hydroelectric projects revealed their long-range functionality (a megaproject has an installed generating capacity of 1,000-plus MW). The real expansion of the hydroelectric sector dates back to the 1930s and parallels the industrialization of the rest of the world. The more industrialized states succeeded in installing hydropower plants in choice locations; states entering the industrial age were at the beginning of tapping into their hydroelectric potential. Hence, the data reveal significant regional difference in hydroelectricity generation and point to notable shifts in the standard of living once electricity became available to a growing number of users.

In regional evaluation and by select time intervals, the swift acceptance of hydroelectricity in South America and Asia stands out in the total advances in installed capacity (measured in megawatts) as well as in the annual consumption rates.
(measured in kilowatts per hour). Table 1 provides the installed generating capacity values since 1950. Africa stands out as the world’s electricity stepchild, and that condition cannot be disconnected from that continent’s difficult history. While Asia recorded the largest absolute hydroelectric installation increases, in relative terms, hydroelectric power’s share in total electricity generation declined as electricity demand outpaced hydropower construction schedules. Worldwide, this pattern of absolute installation values made significant gains, though the relative hydroelectric dependence declined.

Future projects for continued expansion of the hydroelectric sector will depend on long-term energy needs and planning. In the industrialized regions, increased expansion of the hydroelectric sector is predicated on the quest for maximum energy independence, minimal environmental impact (though with notable exceptions for megadam projects in countries such as China, India, and Brazil), reduced greenhouse gas emissions, optimal energy conservation, and especially low cost per kilowatt of installed generating capacity and long-term project productivity.

Hydroelectricity is not anchored in the past. Hydroelectricity will register notable changes in the following decades as the potential of seawater will be tapped. The other challenge will be generating hydroelectric power without the construction of dams. These evolving changes are responses to global concerns over environmental conservation, the more intensive use of human skills, and the significantly reduced dependence on the physical resource base. These shifts in efforts and emphasis will significantly increase the energy dependence on hydropower-derived electricity. Emerging changes in the hydroelectric sector may
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Table 1 Installed electricity and hydroelectricity capacity data (in megawatts and percent) for the world, its regions, and selected countries

converge with solving the superconductivity challenge. It is hoped that the world’s oceans will provide the low-cost hydroelectricity that a clean world depends on.

Rolf Sternberg

See also Energy Policy; Energy Resources; Renewable Resources; Rivers; Watershed Management

Further Readings


HYDROLOGICAL CONNECTIVITY

Hydrological connectivity defines the spatial and temporal pattern of the links among surface or subsurface water networks flowing across a landscape, and hence, it determines the ease with which water may move across a landscape or through a river system. Hydrological connectivity is a dynamic property of the system, and its long-term integration can be expressed using probabilities whereby a point in the landscape connects with another point or with a receiving water body such as a river or a lake. The strength of the hydrological connectivity is a function of two factors: (1) the surface facilitating or impeding the movement of water and (2) the temporal structure of the rainfall or river flow time series driving the movement.

The degree to which the surface facilitates or impedes the movement of water is determined by the surface properties and their spatial structure. As water moves along a terrestrial flow path, at each point there are four options available for water movement: (1) evaporation, (2) entering depression storage, (3) infiltration, or (4) moving along the flow path down the slope. The water may move down the slope along the surface, through the subsurface within the soil, or through a groundwater aquifer. The characteristics of the landscape and storm determine the set of probabilities that the water will move in each of these directions. For example, in many semiarid environments, there is a two-phase pattern of infiltration rates controlled by vegetation, with areas under vegetation having far greater infiltration rates. This pattern leads to short overland flow travel distances and hence hydrological disconnection. Under temperate conditions, subtle topographic hollows can cause overland flow to infiltrate and cause disconnection. Flow concentrations, in the form of rills and channels, promote efficient transmission and hence facilitate connection. Points further from the river channel have longer travel times, and hence, there is a greater probability of disconnection along the flow path. Therefore, the catchment has to be in the runoff-generating and transmitting state for longer for the flow to connect. This relationship with the temporal characteristics of storms led Bracken and Croke to define two types of disconnection: Type 1, where the points along a flow path that are more prone to wetness become dry before the material delivered from upstream has passed through them, and Type 2, where the event is of insufficient magnitude and duration to wet the driest point along a flow path.

Indices

It is possible to describe hydrological connectivity at the landscape scale with the Network Index through the analysis of potential soil wetness and flow paths. The Network Index describes the catchment average wetness required both for a point in the landscape to be generating runoff and for there to be a continuous flow path from that point to the river channel capable of transmitting the water, and hence it describes the propensity for Type 2 disconnections. In 2006, Reckendorfer, Baranyi, Funk, and Schiemer applied a connectivity parameter based on the number of days per year that the main channel was able to flow into the adjacent wetland. In 2007, Lasne, Lek, and Laffaille used a typology based on the type and frequency of connections
between the near-channel water areas and the main channel.

**Simulation**

A number of hydrological simulation models are capable of tracing the flow paths taken by water through a catchment and hence are able to give insights into the dynamics and patterns of the predicted hydrological connectivity. One approach is the hydroAgent model, which is an agent-based model coupled with the CRUM-2D hydrological model. Another approach is the Lagrangian particle-tracking model, SLIM, which has been coupled with the ParFlow model of Maxwell and colleagues.

**Applications**

Hydrological connectivity theory is used in two key areas within the environmental sciences: (1) nonpoint source pollution risk modeling and (2) ecohydrology. It is established that for a pollutant to reach a river or lake there must be both a point-scale risk and a connection to the receiving water body to form a critical source area. This philosophy has underpinned many of the nonpoint source pollution risk tools developed. For example, the Phosphorus Index (P-Index) uses a threshold distance to the river channel to determine greater connectivity. The Sullivan County’s Interactive Mapping Application (SCI-MAP) risk-modeling framework of Reaney, Lane, Heathwaite, and Dugdale, in a publication in review, uses the Network Index measure to capture a detailed representation of the hydrological connectivity. Hydrological connectivity has been applied in ecohydrology to describe the interactions between the main river channel and the adjacent, but occasionally connected, water bodies. For example, Reckendorfer and his colleagues found that the number of species followed a hump-shaped distribution with a peak at a hydrological connectivity level of 1 month per year.

S. M. Reaney

See also GIS in Water Management; Hydrology; Network Analysis; Nonpoint Sources of Pollution; Rivers; Surface Water; Water Pollution; Watershed Management

**Further Readings**


**Hydrology**

Hydrology is the multidisciplinary science that seeks to understand, describe, and predict the occurrence, circulation, and distribution of water on and under the Earth’s land surface, as well as the physical, chemical, and biological interactions of this water with the terrestrial environments of our planet. The science of hydrology uses the study of physical laws to determine the modes and amounts of the movement of water through the hydrologic cycle on Earth, and as such, hydrology incorporates elements of meteorology, climatology, oceanography, glaciology,
hydrogeology, and ecology in its studies. Such integration is not commonly done and requires attention to processes at work deeper in the upper crust of the Earth, including volcanic activity. Understanding the waters of the Earth and assessing the locations, interactions, amounts, and changes in the water masses of the planet require a discussion of the deep tectonic water cycle; the shallow-surface hydrologic cycle, in which water cycles between liquid, vapor, and solid states; and the hydrological accounting systems used to track the volume of water. After reviewing these concepts, this entry considers the threat posed by global water scarcity and the growing importance of hydrology in understanding and responding to it, especially in light of the human impacts on water availability. It concludes with a brief look at the challenges posted by water law in North America.

**Tectonic Water Cycle**

In terms of a rough calculation of the total water of the Earth, the surface of the planet is considered to have one ocean mass (1 OM). Earth originally had about 4.2 OM locked up inside it when it first accreted from space about 4.5 billion yrs. (years) ago. The 1 OM now on the surface had escaped since accretion to form the modern oceans, leaving about 0.2 OM behind in the upper mantle. The lower mantle still has about 3 OM locked up inside it. The molten core of the Earth beneath has no water at all in it. The tectonic water cycle has water constantly escaping from inside the Earth through volcanic eruptions on land and beneath the sea. In fact, more than 50% of all volcanic gas comes out as steam in new or juvenile water, to be added to the surface supplies. Some water is also returned to the interior of the Earth as it goes down subduction zones or is absorbed directly into the undersea floor.

Yearly fluxes of water through the Earth’s upper crust include (1) shallow hydrologic flow on the continents, amounting to about 37,400 km³ (cubic kilometers) per year, and (2) free hydrostatic water movement to depths of possibly as much as 15 km in sedimentary basins on continents, where the sediments compact and emit water like a sponge under their own weight at compactive water expulsion rates of ~3 km³/yr. Beneath the oceans, in the seafloor plates to depths of ~5 to 7 km, there is total flank convection or free convection of water at rates of >240 km³/yr. Close to the volcanic rift zones in the oceans, forced convection of water in the rocks of the sea bottom amounts to ~40 km³/yr.

**Surface Hydrologic Cycle**

The hydrologic cycle at the uppermost surface of Earth is a continuous and cyclic process by which water is evaporated from the oceans and blown as vapor and clouds over landmasses, where uplifting and cooling of the air masses causes further condensation and precipitation. The resulting precipitation is stored as snow and ice at high altitudes and high latitudes in snowfields and glaciers, runs off as overland flow in rivers, or goes into underground flow and groundwater storage. Some underground water flows back out through porous and permeable stream banks and into stream channels as base flow. Other stream water and groundwater goes into lakes and then evaporates back into the atmosphere or goes into plant roots and is transpired as vapor into the atmosphere as well. The hydrological cycle is powered by solar energy, the rotation of Earth, and the gravitational attraction of the planet. It is modulated by winds and the latent heat absorbed in evaporation and released in condensation.

The analysis of movements of water in the hydrosphere of Earth is fundamental, so an accounting of all the inputs and outputs in any particular place, or for the whole world, requires various water balance equations. Fundamentally, the water balance equation relates precipitation \( P \) to the runoff or river discharge \( Q \), the evapotranspiration \( ET \), and any changes in storage \( S \), thus \( P = Q + ET + S \).

The water balance can also be calculated to incorporate the atmosphere so that the water vapor flux into and out of the system can be included. The surficial or subsurface soil moisture and groundwater storages can also be calculated to enable better predictions for agriculture. Water balance relations in any area exert profound control on human land use possibilities.
The hydrological cycle of a catchment or drainage basin consists of one major input, six kinds of storages, seven transfer processes, and three outputs. Collectively, these inputs, storages, transfers, and outputs constitute a convenient analysis method of the hydrologic system of the world, which enables more precise determinations of a vital resource. The major input in the hydrologic system is, of course, precipitation in the form of rain, snow, sleet, hail, drizzle, and fog. Precipitation intensity and volume, coupled with atmospheric temperatures that affect the solid precipitation by keeping it solid or melting it, control the output from a drainage basin. The storages in a catchment include interception, vegetation, surface basins, and channel locations above the ground surface and soil moisture and groundwater below. Water that is intercepted is held in leaves, branches, and stems or inside the cells of the vegetation, where it was obtained from the soil moisture. The three types of soil moisture are (1) hygroscopic water, which is held tightly at the molecular level around soil particles so that it is unavailable to plants; (2) capillary water, which moves upward in fine threads in the vadose zone of aeration from the water table; and (3) gravitational water, which drains slowly downward to replenish the groundwater in the zone of saturation beneath the water table.

Water transfers through the hydrological cycle include the above-ground throughfall and stemflow, surface runoff, and channel flow; the infiltration movement into the ground; and the below-ground percolation, throughflow, and groundwater flow. Throughfall occurs from leaves, and stemflow of water runs down tree trunks after it has been intercepted from atmospheric precipitation. Surface runoff or overland flow produces the rivers of the world. Infiltration of water into the soil is controlled by the nature and properties of the soil, as its grain size, compaction, porosity, and permeability facilitate or impede water transmission. Percolation downward and throughflow laterally, occur through the interconnected pore spaces and small cracks and joints in the soil and rock of the vadose zone or the zone of aeration above the water table. Below the water table, where all openings are saturated with water in the unconfined water zone, or even deeper in the confined or artesian water zones underground, groundwater flow occurs in all directions as a result of pressure differentials. Catchment outputs are then the evaporation of surface water bodies, transpiration through the stomata pores on leaves, and the runoff of rivers.

**Hydrological Accounting Systems**

Because of the ever-increasing need to keep track of the amount of water available for use by humans, most developed countries have hydrological accounting systems that make good estimates of water volume and percentages in all its forms and places. This process necessitates the acquiring and public maintenance of things such as the following:

- Streamflow records
- Precipitation records
- Topographic maps
- Groundwater data
- Evaporation and transpiration data
- Data on the quality of the supply

Thus, the many portions of the hydrological cycle of Earth can be measured and simulated on ever-finer spatial and temporal scales. Robust models of each hydrological subprocess have been developed, with the result that the current and future status of the global water system are fairly well understood and predictable. The social aspects of water use are not easily available, however, and are therefore less predictable. Nonetheless, warnings of decreased water availability in the future are likely, in part because of increased population as well as the uncertainties associated with global climate change.

**World Hydrological Accounting**

In the accounting system that has been developed in the past four decades since the International Hydrological Decade of the late 1960s, we can see that of the total evaporation on Earth, about 85%, or ~428,000 km³/yr., is from the sea and another 15%, or ~67,000 km³/yr., from the land, which also includes transpiration from plants. The total precipitation over the land is about 25%, or 110,500 km³/yr., whereas over the sea, it
is about 75%, or ~384,000 km³/yr. The total storage of water in the rivers of the world is only ~2000 km³, and in lakes it is ~175,000 km³. About 8% returns to the sea as runoff and groundwater, with perhaps ~40,700 km³/yr. going in through rivers, although if the groundwater discharge that goes into the rivers as base flow were included, then the rivers’ discharge would be something more like ~45,500 km³/yr.

If we consider the total water mass at the surface of the Earth, some 1,338 x 10⁶ km³, or about 97%, is in the ocean, while 2.5% is freshwater. Now, if we take that 2.5% as 100% of the freshwater potentially available to humans, we find that about 78% is surface water, with the remaining 22% being groundwater (~23,400 x 10³ km³). This underground water is divided up as 0.18% (17 x 10³ km³) soil moisture, much of which is available for plants; 11% shallow groundwater; and 11% deep groundwater. That most essential 78% of the water on the surface is then considered as 100%, with the large quantity presently stored in ice and glaciers at 99%, or some 25,500 x 10³ km³, whereas freshwater lakes have only 0.33%, saline lakes 0.28%, and rivers and streams 0.003%, with the total in the atmosphere at any one time at about 0.03%. Clearly, surface water supplies on the continents are extremely limited, and as climate change takes place, some places may have even less supply than they do now. That is why many scientists regard the 21st century as the most likely time of maximum water conflict between nation-states.

In 1993, the United States withdrew a total of an estimated 1,283.3 billion L (liters) (339 billion gal. [gallons]) of so-called blue water per day from lakes, streams, and underground sources. By 2000, this amount was up to 1,554.5 billion L (408 billion gal.) of water a day, but that is not a lot compared with the much higher rate of increase from 1950 to 1980. In fact, after 1980, water conservation methods had improved enough to cause a flattening out of the rate in the United States. Evapotranspiration from nonirrigated cropland in the world is referred to as “green” water, and it is estimated to be ~7,600 km³/yr. from cropland and ~14,400 km³/yr. from permanent grazing land. This is about one third of the total terrestrial evapotranspiration. At the present time, only about 10% of maximum available blue water and 30% of green water resources are used in the world. This might appear to offer an opportunity for further development of these hydrological resources, but in fact, the high variability of water resource availability in time and space, in spite of artificial storage at ~7200 km³, precludes additional availability.

The predictions of global water scarcity in this century as populations increase and climate changes have led to the recognition of the need for worldwide monitoring and new methods to monitor international impacts. Thus, to assess global water access, a water scarcity index has been proposed: \( R_{ws} = \frac{(W - S)}{Q} \), where \( W \) is the annual water withdrawal from all sectors, \( S \) is the annual renewable freshwater resources. Any region with an \( R_{ws} \) beyond 0.4 is considered highly water stressed. Moderate water stresses range from 0.2 to <0.4; low water stress is from 0.1 to <0.2, and areas with no water stress are <0.1. Water scarcity thus can be easily designated as severe in the well-populated Midwest and much of the intermontane west of the United States, as well as in the heavily populated basins of the Yellow River, Indus, Ganges, and Amu Darya in Asia. This latter point is significant because although the amount of available water in Asia is large, as it originates from the great “water towers” of the Himalayas, the populations and the agricultural irrigation demands are equally large, so that the water stress ratio is the highest among the continents. Nearly 2.4 billion people are currently living in these highly water-stressed areas.

Because of the huge human impacts on hydrological processes, it does not make sense to study only natural hydrological cycles. Accordingly, the impacts of human interventions on the water cycles are increasingly being studied to simulate more realistic analysis of hydrology on a global scale. To do this, some accounting must be made of domestic water extracted and returned to river flow by humans, as well as irrigation water and that sent to industry and then returned to the rivers. Such use of the water resources by humans results in the addition of a great variety of contaminants far beyond the natural additions of salts or other materials that preclude normal use by humans. Degradation of water
quality is to be expected in the anthropogenically modulated or controlled environments in which most humans live. The increase in contamination of freshwater systems worldwide by thousands of industrial and natural chemical compounds is a key environmental problem facing humanity. With a total global runoff of about 40,700 km³/yr., only about 12,500 km³/yr. is actually accessible, although only about a third of it is used. Total water withdrawals are ~4,430 km³/yr., with ~2,880 km³/yr. going to agriculture, ~975 km³/yr. going to industry, and ~300 km³/yr. going to municipalities. In the course of these withdrawals and returns, the fluxes of macropollutants are truly staggering: Total inorganic nitrogen (~75% anthropogenic) is 21 × 10⁶ tons/yr., total phosphorus is ~5.6 × 10⁶ tons/yr., and heavy metals (zinc [Zn], chromium [Cr], nickel [Ni], lead [Pb], copper [Cu], cadmium [Cd], and mercury [Hg]) amount to 0.3–1 × 10⁶ tons/yr. Examples of ubiquitous water pollutants include solvents, petrochemicals, lubricants, flame retardants, detergents, pharmaceuticals, hormones, pesticides, biocides, cyanotoxins, disinfection by-products, as well as metabolites or reactive products from all these.

Future Water Shortages

The science of hydrology that is practiced in most countries considers surface freshwater supplies first and foremost in terms of location, flow and flood characteristics, and other aspects of water in the immediate human environment. Next comes attention to soil moisture for crops and then deeper forms of groundwater, whether it is the unconfined, or water table, water or the deeper confined or artesian aquifers, where water is commonly under some pressure. Further afield from most human environments, the large storage of snow and ice is certainly worthy of notice, especially because in the world of climate change toward which we are heading, the likely melting of so much ice will perhaps help a little in some places. New lands and resources would be opened up in some areas, while other lands will be inundated by the sea as its levels rise. The prospect of disruption of the hydrological cycle, which was considered to have been explained both qualitatively and quantitatively in the late 20th century, now seems quite possible. The human race and its historic, prehistoric, archaeological, and evolutionary precursors have always been at the mercy of slow and rapid climate change, even if it went unrecognized due to ignorance or was denied because of the wishful thinking that “it won’t happen to us.”

The increasing importance of hydrology has been obvious for much of the past half-century as increasingly detailed information on the availability and use of surface and underground water supplies became available. In the early days of the settlement of North America by humans from Asia and later from Europe, Africa, and Latin America, there were always plentiful supplies of reasonably clean and potable water. That is no longer true. In the course of development of the continent, tiny and mammoth dams were built willy-nilly, first to produce power, later for irrigation supplies, and still later as flood control devices. The problem with this multiple use was apparent, however, because dams need to be empty for flood control and full for irrigation and power production; careful meteorological and hydrological record keeping was seen as the best means to enable statistically precise predictions of floods and droughts so that dams could be managed most effectively. A problem with this approach occurs when the climate changes, since past hydrological records do not enable very accurate prediction of the future.

In the wetter regions of Eastern North America, the need for agricultural, urban, and commercial lands since the early European settlement had led to the draining and filling of wetlands such as swamps, bogs, and coastal marshes because for centuries they had been regarded as wastelands. Only in the latter half of the 20th century did their environmental value as important pollution-filtering screens and shoreline protection habitats become obvious. Thus, the relationship of water to land in North America has long been one of damming, pumping, draining, and diverting water to reinvent the landscapes. Swamplands and wetlands have become fields and farms, arid lands have bloomed, and cities have thrived far from water supplies. The 100th meridian splits the continent.
into two regions: the wet east, with more than 50 cm (centimeters) of precipitation a year, and the arid west, most of which has less than 50 cm of precipitation per year. The results for more than a century and a half have been the development of extensive irrigation networks in the American West. Without irrigation, these lands would not grow crops, but with it, the soils can become waterlogged and saline so that plants will not survive. There is always a small amount of salinity in irrigation water, and because plant roots absorb the water but leave the salts behind, the salts can only increase unless they are flushed out through expensive soil desalinization schemes involving sheet flooding and expensively engineered soil drainage schemes.

**Water Law**

A major problem with hydrologic analysis and use of water in North America, however, is that water law was developed several centuries ago and has maintained its hold on legal use whether or not it makes sense in the modern world. Certainly, the rights of prior appropriation of surface water supplies, or “first in time, first in right,” or the nonsensical divorcing of surface water appropriation from underground water appropriation has led to litigation between states; both indicate that new legislation has been required for many years. A further problem in the fair sharing of water between states is that the pumping of water near state boundaries has also resulted in cross-border movement of underground water with no real legal resolution to date. Revisions of water law in North America are likely to be a major issue in future years.

*John F. Shroder*

See also GIS in Water Management; Groundwater; Hydroelectric Power; Hydrological Connectivity; International Watershed Management; Oceanic Circulation; Oceans; Precipitation, Global; Precipitation Formation; Rivers; Surface Water; Urban Water Supply; Water Degradation; Water Management and Treatment; Water Needs; Watershed Management; Watershed Yield

**Further Readings**


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**HYDROTHERMAL ENERGY**

See Geothermal Energy
Ibn Battuta was the greatest medieval traveler and author of an extensive travel account. His full recorded name reflects his North African origin: Shams al-Din Abu 'Abdallah Muhammad ibn 'Abdallah al-Lawati al-Tanji. He was born in Tangier to a family of Islamic jurists and ended his days as a judge (qadi) in rural Morocco.

The story of his travels, which took place between 1325 and 1355, was dictated in Fez to the young court writer Ibn Juzayy (1321–1356) on the orders of the Marinid Sultan of Morocco Abu 'Inan. Ibn Battuta traveled routes extending 3 times those of Marco Polo, but he mostly stayed within the countries under Muslim rule. He was not a learned geographer and made no claims to academic learning, but he was a keen observer of people, places, local cultures, and elites, and his narrative provides rich, vivid, and usually reliable information about the places visited, individuals encountered, and stories heard.

His odyssey started in 1325 with a pilgrimage to Mecca; however, he soon developed a passion for travel and sought new destinations and new routes. At the time of his journeys, Islam was undergoing a massive expansion in South Asia, sub-Saharan Africa, and parts of Eurasia. Ibn Battuta’s account, usually simply called *The Rihla* (Travels), offers unique glimpses into the process of expansion of the frontiers of the *Dar al-Islam* (Abode of Islam) in the mid 14th century. The full title of this book, an important and original example of the *rihla* genre of Arabic travel literature, is *Tuhfat al-nuzzar fi ghara’ib al-amsar wa ’aja’ib al-asfar* (A Gift to Those Who Contemplate the Wonders of Cities and the Marvels of Travels).

The chronology of Ibn Battuta’s travels is not always clear; after completing his first pilgrimage, he continued to travel, mostly in Asia, spending many years in India and visiting Sri Lanka, Indonesia, and China before deciding in 1349 to return to Morocco. This was about the time of the Black Death epidemic, which carried away his mother and eventually himself. On state missions and on his own initiative, he then traveled again (in 1350 to Spain and in 1351–1355 to West Africa). By contemporary count, Ibn Battuta visited the equivalent of 44 countries. Staying either within the territories governed by the Muslim rulers or among the Muslim communities abroad in non-Islamic states, he pursued the company of religious teachers, pious sheikhs, and legists and gained most of his employment and patronage as a raconteur and an expert in the Maliki school of law, common in North Africa. He had an interest in mysticism and miracles and periodically returned to Mecca for repeat pilgrimages (sometimes to escape court intrigue and persecution).

Travel was fraught with danger, and Ibn Battuta suffered the hardships of weather, discomfort, shipwreck, piracy, and robbery. He was an unusually self-aware traveler, inquiring about
itineraries, transport, seasons, and schedules. Early on, he decided never to travel by the same road twice if he could help it and so observed the terrain, economy, and population from diverse routes. He traveled by camel, horse, mule, litter, wagon, and boat and never failed to describe the mode of transportation for himself, his companions, and his hosts. His encounters with queens and princesses provided occasional patronage and protection; he married and divorced the daughters of his learned friends and colleagues, or female relatives of patrons in the service. Such women often declined to accompany him on his journeys, and he resorted to the company of slave girls, purchased or presented to him. A devout Muslim who benefited from the expansionist jihad against non-Muslims, Ibn Battuta admired the piety and learning of some Muslim women (in Mecca and in India) and openly deplored others’ free socialization with men (in Africa) or refusal to cover up (in India and Africa). He was impressed with the high status of women among the Turks and Mongols and distressed by the Hindu custom of widow self-immolation (suttee or sati).

Ibn Battuta’s stories of faraway places and remarkable phenomena were received with some skepticism by his contemporaries, including the great historian and philosopher Ibn Khaldu-n (1331–1406), who met him in person. His book had limited circulation, mostly in North Africa in abridged versions, and did not become well-known until the 19th century. In 2004, Ibn Battuta’s 700th anniversary was celebrated throughout the Arab world; a large shopping mall in Dubai (UAE) bears his name, plays have been written about him, and multiple Web sites recount his travels on the Internet.

Marina A. Tolmacheva

See also al-Idrisi; Human Geography, History of; Ibn Khaldu-n; Travel Writing, Geography and

Further Readings


**IBN KHALDÚN**

(AD 1331–1406)

Ibn Khaldu-n al Hadrami was a great Arab historian and philosopher of history and social sciences. Compared in the West to Thucydides and Machiavelli, he developed a theory of world history embedded in sociology, social psychology, demography, and cultural ecology. He was also active in politics and the practice and teaching of law.

We know of his life from contemporary records and from his autobiography *Kitab al-ta’rif bi-Ibn Khaldum wa rihlatuhu gharban was sharqan* (Information About Ibn Khaldu-n and His Travels West and East). He was born in Tunis to an upper-class family that fled Andalusia after the fall of Seville to the Reconquista and had served the Hafsid dynasty, but he withdrew from politics into mysticism. Both his parents died in the plague epidemic in 1349. In adult life, Ibn Khaldu-n sometimes withdrew from competition for prestigious appointments to pursue contemplative religious or scholarly life. The unstable North African politics is reflected in his political alliances with rulers and courtiers, shifting loyalties, and occasional imprisonments. About 1352, he moved from Tunis to Fez and served the Marinid Sultan Abu Inan Faris. Changes of fortune after the latter’s death in 1358 made him seek success in
Granada, but he was driven out by intrigue and returned to North Africa. After moving from the Hafsid court at Bougie to Tlemcen and again to Fez, Ibn Khalðūn sought refuge with the Berbers in Qal‘at Ibn Salama (1375–1378). That is where he wrote the Muqaddima, or Introduction (often translated “Prolegomena”) to his world history. He then returned to Tunis and continued writing, now in the service of Abu 'l-Abbas, the former ruler of Tlemcen who had conquered Tunis. His loyalty under suspicion, he left in 1382 under the pretext of performing the hajj, or pilgrimage to Mecca.

After reaching Alexandria, he went to Cairo, where the Mamluk sultan Barquq soon appointed him a grand Qadi (supreme judge) of the Maliki school of religious law, common in North Africa. This was the start of a new period and a new career for Ibn Khalðūn. He resigned the judgeship or was dismissed five times, received teaching appointments and diplomatic missions, and continued research to amplify his oeuvre, Kitab al-Ibar. The full title translates as “The Explanation and Records of the Early History and Political Events Concerning the Arabs, Persians (non-Arabs), and Berbers, and the Supreme Rulers Who Were Contemporary With Them.” The Introduction and First Book became known independently as the Muqaddima in Ibn Khalðūn’s lifetime. Books 2 through 5 are a history of the Arabs, Persians, Jews, Greeks, Romans, and Berbers. Book 6 deals with the theory of knowledge and the relationship between science and civilization as an outcome of social organization. There is no full translation of the complete work. The Muqaddima is available in the three-volume English translation by Franz Rosenthal and in an abridged paperback edition.

In 1401, Ibn Khalðūn was recruited by the new Sultan Faraj to accompany him to Damascus, then besieged by Timur (Tamerlane). From the walls of the city, he was lowered to meet Timur and spent several weeks in his camp, where he was invited to speak of history, the Abbasid caliphs, the Maghrib, and Ibn Khalðūn’s personal and family history. He also negotiated release for himself and his escort, but Damascus was surrendered and sacked. Back in Egypt, Ibn Khalðūn twice regained the Maliki judgeship and died in Cairo while in office.

Ibn Khalðūn pioneered the critical study of history with an emphasis on reason and empiricism. He is also often called the founder of sociology, political science, demography, and even economics. Because his theory of civilization (’umran) is focused on the urban environment as the cradle of culture, as opposed to the tribal and nomadic lifestyle, he is also viewed as an environmental historian. Ibn Khalðūn’s interpretation of human history is centered on the theory of cyclical progress—the rise and fall of dynasties originating from nomadic societies that build empires and settle in cities. The rise of political dynasties depends on the sense of tribal cohesion, or ’asabiya. The nomads are rough and savage but hardy and frugal; they are freedom loving, upright, and self-reliant and make excellent fighters. Towns are the seats of crafts and culture, and luxury corrupts the people and undermines their solidarity. Rising expenditures require higher taxes, which discourage production and reduce revenue. The rulers are separated from the people who originally brought them to power, and decline sets in within three generations. In their weakened state, they are conquered by another group held together by ’asabiya, which may be reinforced by religion. The conquerors inevitably wish to emulate the conquered, they are seduced by luxury and the lure of royal power; the state weakens, the population decreases, the group relationship deteriorates, and decay sets in.

Ibn Khalðūn consciously combines an objective and empirical methodology of historiography with the analysis of psychological and environmental factors in the development of social and political organization. He draws extensively on his personal knowledge of the Berber tribes, their habitat, and their history. For a geographical setting of his world history, Ibn Khalðūn draws significantly from the introductory sections of the Nuzhat al-mushtaq, an outstanding universal geography by the 12th-century North African geographer al-Idrisi. Some manuscripts of the Muqaddima are illustrated with the round world map copied from al-Idrisi’s Geography.

Marina A. Tolmacheva

See also al-Idrisi; Ibn-Battuta
ICE

In the 50 yrs. (years) between the third (1957–1959) and fourth International Polar Year (2007–2009), our understanding of the ice, as a material substance and geomorphic agent, has been transformed. Considered a robust frigid material in the 1950s, the ice was something to be endured, conquered, and studied. As prolonged scientific inquiry and research programs in ice-based places increased during the 1950s, our understandings of these complex material geographies significantly increased, as did the sciences of glaciology, seismology, and ice sheet dynamics. Poised on a delicate, irreversible climatic threshold, the ice is now a key indicator of environmental change and its consequences for human societies, from the glacial meltwaters of the Himalayas to the inhabited Arctic.

We live on a planet whose landscape surfaces are predominately shaped by the geomorphic action of ice, particularly that of glaciers and ice sheets. Scientists collectively refer to this ice-based environment as the cryosphere (Figure 1). Derived from the Greek word kryo for “cold” or “too cold,” it is the term that describes collectively the portions of the Earth’s surface where water is in a solid form, including ice caps, snow, sea ice, ice shelves, ice sheets, glaciers, and permafrost. The cryosphere takes many forms. Topographically, these range from the high places of mountaintops and glacial cirques to the sea ice of the high Arctic and the quaternary ice sheets of Greenland and Antarctica. The cryosphere is now understood as an integral part of the global climate system, with important linkages and feedbacks to the stability of global climate and responses to anthropogenic-induced climate change. Warming of the major ice regions of the Arctic and Antarctic will cause vast quantities of water to be released and will affect sea-level rise and ocean current circulations.

The cryosphere is also an integral part of the weather imaginaries and a media icon of climate change. As a site of visually dramatic weather events and looming environmental catastrophe, ice-based environments have moved from the peripheries of the Western geographic imagination to the center of debates on climate change; satellite maps of ozone holes over the poles, melting Siberian permafrost, the “opening” of the Northwest Passage, the impact of melting glaciers on water supplies, ice sheet collapse, and future sea-level rise are part of the visual lexicon of climate change. Far from the historical aesthetic of “icy spaces” as sites of vigorously demanding exploration and robust masculinities, the ice is now imaged and imagined as a vulnerable materiality that exhibits the effects of climate change.

Retreating Ice

The rates of temperature change in the Arctic are double the rate of change of the Earth as a whole, and this has had a dramatic effect on icescapes and the lives of indigenous peoples in the circum-polar North. Evidence of this can be found in the rapid decrease in sea ice, shorter winter seasons, decrease in the age of sea ice, thinning of the Greenland ice sheet, melting of Siberian permafrost, and retreat of glaciers in all areas of the Arctic. The most dramatic event in recent years has been the opening of the fabled Northwest Passage in September 2007 to shipping for the first time in 8,900 yrs. Arctic warming and the

Further Readings

Ibn Khaldu’n on the Web: http://historymedren.about.com/od/ibnkhaldu/ibnkhaldu_on_the_Web.htm
Figure 1  The cryosphere, world map

subsequent ice retreat are caused by increased concentrations of greenhouse gases as well as other anthropogenic pollutants such as methane, tropospheric ozone, and black carbon. This rapid change in ice conditions is altering the ecosystems throughout the circumpolar North and causing increased stress on human and nonhuman inhabitants. Worryingly, the retreat of ice in the Arctic increases the likelihood of more development and resource extraction in the Arctic, thus increasing fossil fuel emissions.

**Modeling the Ice**

While there are many unanswered questions about the effects of warming on the ice, the material archives of the ice have revolutionized our view of the Earth and our understanding of climate change. Ice cores retrieved from the ice sheets of Greenland and Antarctica have helped scientists correlate important data for future climate prediction based on the past records of atmospheric changes that are recorded in tiny trapped bubbles of air entombed in the ice over the past 800,000 yrs. The most startling discovery has been that climate change is not a process of slow, gradual change but climate is nonlinear—it flickers and spikes: Abrupt events can occur over months and years, not hundreds and thousands of years as scientists previously thought. This knowledge of abrupt climate change has profound implications for the rate of human adaptation and the resilience of communities when facing sudden rapid change.

The other major technology of ice is the Earth-observing satellites that monitor and provide data...
on the major ice sheets and sea ice. What these satellite images tell us is that both sea ice and ice sheets are changing much faster than was appreciated by scientists in their computer modeling of the ice. Today ice sheets can be monitored through unprecedented temporal and spatial scales. This has prompted scientists to rethink the ice sheet timescales, and rather than presuming that the large ice sheets of Greenland and West Antarctica would not react as quickly as glaciers to temperature changes, satellite data are indicating large-scale changes in the ice, alongside the rapid retreat of smaller glaciers around the world (Figure 2). These major questions about the rate of change in large-scale ice sheets, as recently highlighted by the Intergovernmental Panel on Climate Change, highlight uncertainty about sea-level rises and the future stability of the large ice sheets.

While scientists grapple with questions in the laboratory of ice, glacial retreat and the failure of nonpolar glaciers have far-reaching consequences for societies that live in ice regions, or depend on glacial melt for water supplies, and the ecosystems that this glacial melt supports. In recent years, the changing environmental conditions of the Arctic have given rise to several new challenges to governance by circumpolar peoples, most notably the petition by the Nobel Prize nominee Sheila Watt-Cloutier to the U.S. government for the “Right to Be Cold.” As scientists attempt to understand the complex interdependencies between ice, temperature, and fossil fuel consumption in changing
global climates, geographers and publics attempt
to map the responsibilities that connect fossil fuel
consumption in Western societies to the changing
icescapes of the Arctic, Himalayas, and Andes,
and social scientists try to assess the impact on
communities and societies. Many questions remain
about how the ice will respond to increasing global
warming and particularly the effect of polar ampli-
fication on the last two remaining ice sheets from
the Quaternary period in Greenland and Antarc-
tica. One thing that is certain is that the ice is on
the move, changing state, changing mass balance,
and changing both the human and the biophysical
worlds.

Kathryn Yusoff

See also Climate: Polar; Glaciers: Continental; Glaciers:
Mountain; Periglacial Environments; Poles, North and South

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Figure 2  Projected temperatures in the 21st century
Identities help us know who we are and who we are not. Collective or social identities serve to order social and political relations between different groups, while personal or individual identities, sometimes called psychic identities, are crucial in the formation of subjects and allow for identification of individuals with groups. Geographers are interested in identities because they are spatial phenomena in that people identify with particular places, landscapes, and territorial entities. These can be, for example, local, regional, or national identities. With the emergence of the modern nation-state system and modernity, national identity was for a long time considered a more important identity than other identifications. Nations, as Benedict Anderson suggested, are groups of people who invent themselves as “imagined communities” on the basis of a common history, culture, or heritage, thereby defining who is a member of a national group and who is not. These definitions of membership create boundaries between “us” and “them.” In the context of nation-states, such social group boundaries are thought to be reflected in the actual borders of states, but social boundaries also delineate ethnic or racial groups that do not necessarily lay claim to territory.

Recent globalization has shown that privileging the nation-state as the site of primary identification is problematic. Globalization and transnationalism have also served to highlight an important aspect of identities that had long been neglected: that the idea of homogeneous (national) identity needs to be critically examined and corrected toward an understanding of identity as not organic or static but as emerging in specific historical, social, and political contexts.

Identities are neither neatly nested in hierarchical spatial entities nor are they singular, nor are identity and geography easily mapped onto one another as early work in geography and the social sciences assumed. This entry considers identities in their multiplicity and in their relationship to geography, emphasizing the fluid and situational character of both identities and space. Creating group unity on which identity is based does not erase within-group differences or power imbalances. Gender, religious, class, or generational identifications, and different interests exist simultaneously within groups, and multiple identifications frequently conflict as individuals try to negotiate their identities in different social settings and places. This approach to identity as multiple identifications forms a break from widespread, earlier notions of identity as stable and occupied Western philosophy in much of the 20th century. Earlier ideas common in Western philosophy of an assumed coherent subject have been supplanted by notions that the human subject is constituted out of multiple identifications and of difference that do not necessarily amount to a coherent and consistent whole.

Scholars now largely agree that identities are constituted through social relations with others. There are, however, different explanations with regard to how subject formation takes place, with the most prominent approaches deriving from the constitution of the subject in and through discourse, psychoanalytic approaches to the subject, and conceptualizations developing from combinations of these approaches that aim to resolve some of the problems inherent in each.

Conceptual Approaches to Identities

Poststructural and postmodern scholarship have moved the understanding of identities away from fixity of identity and toward understanding identities as constructed in relation to difference. Conceptualizing identities in this fashion posits that identity is not, as assumed earlier, coherent and stable, but rather that identities are multiple and emerge as identifications in social interactions between different people and between individuals and groups. In fact, identities and identifications (and with them, human subjectivity and subject formation) are relational as they rely on others to come into existence. Identities are socially and politically constructed through the everyday life interactions of individuals and groups—that is, through individual identification and group formation, shared experiences, and the narratives that groups tell about themselves. For an individual to develop an identification with someone, there needs to be someone (or group) to identify with.

Another aspect of identifications is that they are also influenced by external ascriptions of
identity. Discourses about and representations of groups are integral to the processes of identity construction. It is therefore necessary to analyze identities in relation to and within the institutions and discourses that enable and constrain them in order to also analyze the power relations that constitute them. Discourses always are supported by underlying power, and they are simultaneously exertions of power. Uneven power relations within a society enable certain segments to assume the authority to label, categorize, and thereby define groups, often as others that differ from a certain norm. Official categorizations in the census are but one example of how labeling and categorization construct identities. As groups internalize such ascribed identities, processes of identity construction become perpetuated and reinforced. Discourse always implies power as it produces meaning and ideas, and identities can only be understood if the configurations of power in which they emerge are taken into consideration.

More broadly, then, the construction of identities can be understood as a dialectical process. This dialectic involves knowing oneself as well as everyone else. In particular, knowledge of others is important in defining one’s identity. Stuart Hall (1997) argues that

when you know what everybody else is, then you are what they are not. Identity is always, in that sense, a structured representation which only achieves its positive through the narrow eye of the negative. It has to go through the eye of the needle of the other before it can construct itself. (p. 21)

Identities thus emerge in the articulation of relational and representational identifications with one another rather than in only one of these realms.

These notions of identities are partly influenced by the theories of discourse as constitutive of the human subject as developed by Michel Foucault in *The History of Sexuality*, in which he traces the development of new discourses and categorizations emerging in the 18th century that serve to order and discipline human subjects. These new discourses of, among others, homosexuality and mental illness established human subjectivity as the effect of power relations. Discourses here serve to naturalize certain behaviors and thereby create the normality that human subjects conform to. Uneven power relations allow the majority of the population to structure categories and representations that, in turn, structure power and consolidate the symbolic dominance or hegemony of the majority.

The work of Frantz Fanon allows for examination of the relationship between external ascription of subject positions and the internalization and struggle of individuals with such identifications. In his work, Fanon draws on his training as a psychiatrist to examine the colonized and racialized subject. In *Black Skin, White Masks*, Fanon describes the moment when a racialized colonial subject becomes fixed into his subject position as a black man just in the instant when a little white girl calls him so. Fanon analyzes how this black man, the racialized colonial subject, becomes aware of and internalizes that ascription of race and otherness in relation, and inferior, to the white colonizers. This psychosocial analysis shows the interplay between discursive ascriptions of identity and psychological and subconscious processes in the process of subject formation.

More recent postcolonial scholarship has drawn on both poststructural and psychoanalytic theories in its conceptions of identities and identifications. Psychoanalytic approaches heavily influenced Homi Bhabha’s thinking about identities as identification. He developed his ideas drawing on Jacques Lacan and Fanon, arguing that identifications do not simply confirm an already existing identity. Identification, for Bhabha (1994) is

never a self-fulfilling prophecy—it is always the production of an image of identity and the transformation of the subject in assuming that image. . . . Identification . . . is always the return of an image of identity that bears the mark of splitting in the Other place from which it comes. (p. 45)

Here, the constitutive outside of identification becomes part of the human subject.

**Identity Politics**

Group identity cannot be reduced to being other than another group or individuals. While identity is not natural or inherent, and requires
differences and a constitutive outside, identity is often able to translate such difference into otherness in order to assert its own continuity and strength. To achieve certain goals, group identity may become defined as opposition to an Other—a group, an individual, or a more abstract threat. Social boundaries then are meaningful in that they symbolize and delimit a perceived unity within from the Other outside. The goal of identity formation, and more so of identity politics, is the construction of boundaries that exclude others to mobilize based on this (perceived) naturalized identity in order to accomplish specific, political goals. Being part of one group, in this line of argument, is diametrically opposed to membership in the other group. Such binary oppositions serve to strategically reduce the complexity and multitude of identities of groups or group members to a dichotomy of “us” versus “them” in order to facilitate political mobilization. Group identity becomes strengthened, while the Other’s complexity becomes locked into a specific identity and reduced to a single characteristic against which one’s own group mobilizes. Identity politics thus reduces the dimensions of difference to create a basis for collective action. Essentializing particular aspects of identity, identity politics may serve progressive as well as reactionary political purposes. In the civil rights struggle in the United States, identity politics served to expand human and civil rights for African Americans, thereby mobilizing for progressive political goals. On the other side of the political spectrum, demonizing Muslim populations as the Other serves an identity politics aimed at achieving particular geopolitical goals or the exclusion of Muslims in the West.

**Performativity and Hybridity**

Feminist, poststructural, and postcolonial scholarship offer different conceptualizations of political potential when rethinking identity, identifications, and subject formation. Judith Butler’s concept of performativity shows that identity categories need not be fixed, despite attempts at continuous ascription. In conceptualizing identities as performative, that is, in positing human subjectivity as enacted in the practices of subjects, Butler opens up the possibility for change and counters the fixing of categories of identity and difference. Her conceptualization allows for individuals’ practices to disrupt and change the meaning of identity categories by enacting these ascribed categories differently, and thus to counteract the tendencies of ascribed identities to fix such identities as “natural” or naturalized. Butler argues that the human subject only emerges as it performs its identities in relation to enabling and constraining discourses rather than preexisting discourses or norms that socialize a partially formed subject. There is no previously existing source of identity; rather, identity comes into being in the practices, actions, and gestures of subjects that reference discourses. Conceiving of identification in this manner emphasizes the agency of decentered subjects. That is, by performing them, subjects are able to change identifications, albeit within limits and constraints. Performativity opens up a space for struggles against the ascription and fixing of identities onto subjects, and thus a space for resistance. However, Butler cautions that performativity may not be naively interpreted as liberating the subject from ascribed identity. Rather, subjects’ practices can also contribute to a recurring performance of ascribed identities that may simply reinforce such identities rather than making space for new identifications to emerge.

Another attempt at rethinking notions of identity is the concept of hybridity, which is deemed to disrupt the structures and historical contexts it emerges from, thereby opening up new possibilities for progressive politics and resistance. Hybridity, however, is not simply a mix of previously existing identity and difference. Instead, Homi Bhabha suggests that hybridity emerges out of the traces of other meanings and discourses, combining them to new meanings or representations. It is important to note in this context that these other meanings are not considered original or prior, just temporally earlier. Hybridity, as Bhabha conceives it, does not necessarily resemble other meanings but is a new negotiation of new meanings and representations. Hybridity seeks to resist binary oppositions of culture, of us versus them, or hegemonic culture and the oppressed and thus opens up a space that moves beyond essentialized identities to unravel the margin (however abstract) as the site of resistance.
There are limitations to conceiving of hybridity as abstract space that is “in between” and not located or rooted as necessarily progressive. Geographers have cautioned not to adopt (spatial) metaphors and concepts such as “hybridity” uncritically. While the emancipatory potential of hybrid identities for resistance cannot be denied, hybridity might also become complicit in reifying hegemonic narratives and dominance. Other criticism takes issue with the notion of hybridity as abstract space of resistance because the abstract may be too easily appropriated for reactionary purposes rather than counteracting hegemonic power.

**Identities and Changing Geographies**

These changing conceptions of identities also influence the ways in which geographers consider relationships between identities and space. Recent geographic work has moved away from earlier studies that assumed identities as homogeneous, coherent, and easily mapped onto space. Such work paid little attention to differentiations within groups and tended to assume identity as stable and spatially fixed. Early works in urban social geography posited that areas in cities were characterized by bounded identities such as race, ethnicity, and immigrant nationality/origin.

Although the conceptualization of identities has changed, the relationship between identity and spatial entities remains a central theme in geography. Parallel to criticism against the problematic notion of “identity” as coherent or singular, numerous criticisms have been levied against earlier studies and conceptions of identity as homogeneous and as easily mapped onto space. Identities, geographers now argue, are enacted in relation to space. Contrary to earlier assumptions of identity being easily mapped onto spatial entities, space and identity are co-constructed. Geographers are specifically interested in the ways in which identities are co-constituted with territory, space, place, and landscape.

Landscapes, an important feature of humanistic geography, for instance, continue to be associated with identification and the ways in which social life plays out and is articulated. Contrary to humanistic geography, however, landscapes, in more recent approaches are considered as both expressions of identities and central to creating identifications. Both are always in the process of becoming. Similarly, feminist geographers who analyze the relationship between places and identities emphasize that places are central to expressions of identities as well as to exertions of power among and between groups. Sacred spaces, religious places, and communal locations are but some examples that highlight how power and identities are enacted in relation to them. For example, feminist geographers have analyzed how communal places such as churches, temples, and assembly halls help religious groups create and maintain their religious identities while temples also become sites of differentiation according to gender and caste. In these analyses, neither places nor identities are homogeneous or static, and they entail inclusions as well as exclusions. Instead, recent geographic analysis focuses on the ways places and identities are co-constructed and on the ways construction of places and identities involve power relations between different people and groups of people.

The construction of space in relation to identities is both inclusive and exclusive. Discourses that sanction particular identities and behaviors also sanction these behaviors and identities in particular spaces. As certain practices are normalized or naturalized in spaces, these entail exclusions of other practices. The exclusion of women from public space is one example of the ways in which a dominant group, in this case men, asserts its gender identities through producing and sanctioning particular uses of space, which in turn render other types of practices and identities gendered female out of place. These spatial exclusions may intensify polarizations and oppositions. If the Other is deemed dangerous, a fear of or opposition to that Other turns into a fear of or opposition to the space the Other occupies. But such spaces discursively constructed as Other may gain shifting meanings over time as well, as Kay Anderson’s research on Vancouver’s Chinatown shows. Geographic research on urban space and identity emphasizes that spaces of exclusion need to be understood as shifting grids of multiple identifications and differences, the analysis of which allows for disruption, stabilizing ascriptions of spaces as dangerous. In addition, the new geographies of globalization and transnationalism have allowed...
for new connections across space that also enable new multilocal and cosmopolitan identifications.

Patricia Ehrkamp

See also Cosmopolitanism; Difference, Geographies of; Discourse and Geography; Ethnicity; Gays and Lesbians, Geography and/of; Gender and Geography; Globalization; Humanistic Geography; Hybrid Geographies; Nation; Nationalism; Orientalism; Psychoanalysis, Geography and; Postmodernism; Race and Racism; Sexuality, Geography and/of; Structuration Theory; Subaltern Studies; Symbolism and Place; Transnationalism

Further Readings


The term idiographic refers to the unique aspects of individual areas, that is, those that cannot be understood easily, if at all, on the basis of general rules of inference or deduction. Much of geography has traditionally been concerned with the idiographic in the context of regions and places, long mapping the unusual, colorful, and extraordinary. However, the uniqueness of places has also long been at the center of significant philosophical debates about how to study geography.

The tradition of chorology or areal differentiation, which predominated in the early 20th century, was epitomized by Richard Hartshorne, who maintained that geography is an integrative science concerned exclusively with the unique. In this perspective, regions form the highest form of geographic understanding. Idiographic perspectives hold that each region is a unique combination of physical and human elements embedded in the landscape. Smaller regions are more likely to be more internally homogeneous, and broader ones can be understood through the accretion of small units. Upholding the idiographic in this manner essentially disregards the need for general themes or causal properties that transcend regions—the key point of nomothetic (law seeking) approaches to geography. The idiographic approach has thus long been associated with atheoretical empiricist and inductive forms of thought in geography, that is, generalization without explanation or theorization.

Beginning with Fred Schaefer’s famous critique of regional geography in 1953, the idiographic approach began to wane in popularity. The move into a nomothetic science sought to subsume all
the unique details of a place under general laws of understanding that could be applied in all contexts. The attempt to make geography nomothetic and thus “scientific” entailed a shift from regions without theories to theories without regions. This shift corresponded with the decline in popularity of regional geography more broadly.

However, in the 1980s, beginning with Doreen Massey’s well-known work on regions in the changing spatial division of labor, geographers acquired a new respect for the idiographic. The so-called localities school attempted to resurrect the idiographic by approaching it in terms of the historical development of regions over time. Beginning with the observation that no social process unfolds in precisely the same way in different places, this view held that regions acquired unique combinations of imprints of different divisions of labor (i.e., investments, labor market practices, cultural forms). In such a view, general laws of explanation are only observable in unique, idiographic contexts, and the local becomes more than some inexplicable phenomenon—an object of scientific understanding. In an age of globalization, the local is always shot through with the global, requiring a multiscalar approach. Unlike the earlier tradition of chorology, therefore, this approach is theoretically sophisticated and far from the empiricism that plagued earlier attempts.

Barney Warf

See also Chorology; Hartshorne, Richard; Human Geography, History of; Nomothetic; Regional Geography; Regions and Regionalism

Further Readings


Image enhancement is applied to improve the overall visual quality of an image—to smooth or sharpen image features such as edges for better visual interpretation or better subsequent digital image analysis. It is applied to many types of images, such as medical images, digital photography, and remotely sensed imagery.

In geography, Earth’s surface information can be obtained by the interpretation and understanding of images acquired from sensor devices on board satellites and airplanes. Recently, many new remote sensors have been developed that can detect electromagnetic signals in different wavelength ranges with various spatial and spectral resolutions. However, the original images delivered to general users may not display all the surface objects clearly. Human analysts may not be able to distinguish slight brightness differences for different objects on the original images. The objective of image enhancement is to optimize the image appearance and to aid human analysts with particular image interpretation tasks. The evaluation of the quality of the enhancement is usually subjective; it depends on the human eye and on the particular application. Various image enhancement techniques have been developed for remotely sensed imagery. The commonly used methods include contrast enhancement, spatial filtering, and Fourier transform.

In original images, the brightness values rarely cover the entire range of the gray levels (commonly 8 bits or 256 levels). Therefore, the image contrast may be low, or the image appears dark. Contrast enhancement increases the contrast between image objects and between objects and their surroundings by modifying the brightness values of the image pixels. The brightness value frequency distributions or histograms will be changed. The result is an output image with better image contrast for optimal visualization and interpretation. There are several contrast enhancement methods. For example, the linear contrast stretch methods uniformly expand the range of the brightness values to fill the entire range of the gray levels. The histogram equalization method is a nonlinear contrast stretch method, which considers the frequency distribution or histogram of the image brightness values and assigns pixel values based on
equalizing the histogram. As a result, the pixel values are redistributed according to the histogram. Therefore, the contrast is stretched for pixels with brightness values that appear more frequently and reduced for pixels with infrequent brightness values, such as very dark or very bright pixels.

The contrast enhancement assigns a new value to a pixel based on the brightness value of this single pixel. Spatial filtering assigns a new value to a pixel based on the values of a local neighborhood, or a window, of this pixel. Spatial filters include low-pass filters, high-pass filters, and directional filters. Low-pass filters emphasize low-frequency features and have a smoothing effect on the image. High-pass filters emphasize high-frequency features and may be used for edge enhancement and detection. Directional filters can be used to detect edges in specific orientations.

Fourier transform is a mathematical operation to transform the original image from the spatial domain—the \((x, y)\) coordinate space of the image—to the frequency domain. In the transformed Fourier spectrum, the lower frequencies in the original image are plotted at the center of the spectrum, and the high frequencies are plotted away from the center. Various filters can be designed and applied to the Fourier spectrum. For example, a circular low-frequency blocking filter blocks the center of the Fourier spectrum and can be used as a high-pass filter. After filtering in the frequency domain, an inverse Fourier transform is performed to transform the filtered version back to the spatial domain. With the high-pass filter, the result is an edge-enhanced image. With the low-pass filter, the result is a smoothed image.

In summary, image enhancement is a useful digital-image-processing procedure that can improve the visual quality of an image. The selection of image enhancement methods depends on the specific application. For example, when applying low-pass filters, the enhanced image can actually look too smooth and worse than the original image. However, some speckle noises can be reduced or removed. An enhancement method suitable for one application may not be appropriate for another purpose.

Jinfei Wang

**Further Readings**


**Image Fusion**

Image fusion is a technique to combine multi-source images such as a high-spatial-resolution panchromatic or radar image and a lower-spatial-resolution multispectral image to produce a high-spatial-resolution multispectral image. Ideally, the fused image inherits high-resolution spatial information from the panchromatic or radar image and preserves the original spectral characteristics of the multispectral image. Most Earth observation satellite systems provide two types of image data: a panchromatic image with high spatial resolution and a multispectral image with lower spatial resolution but higher spectral resolution. To effectively use such images, image fusion techniques can be employed to combine the high-resolution panchromatic and low-resolution multispectral images into one color image. Such techniques can extend the application potential of remote-sensing image data.

A variety of methods for fusing panchromatic images of high spatial resolution with multispectral images of lower spatial resolution were developed. Pohl and Van Genderen grouped the existing image fusion techniques into two classes: (1) color-related techniques such as intensity-hue-saturation (IHS) and hue-saturation-value (HSV) fusion methods and (2) statistical/numerical methods such as principal components analysis (PCA), high-pass filtering (HPF), Brovey transform (BT), regression variable substitution (RVS), and wavelet methods. Ranchin and Wald distinguished three groups of fusion methods: (1) the projection and substitution methods, (2) the relative spectral contribution methods, and (3) the methods relevant to the ARSIS (the French acronym for “spatial
resolution enhancement by injection of structures”) concept. There are also some hybrid methods that use combined methods from more than one group. Among the existing fusion methods, the IHS transform and PCA methods are the algorithms most commonly used by the remote-sensing community.

Problems and limitations associated with the available fusion techniques have been reported by many studies. The most significant problem is that the fused image usually has a notable deviation in visual appearance and in spectral values from the original image. These deviations, called color distortions, affect further interpretation, especially when the wavelength range of a panchromatic image does not correspond to that of the employed multispectral image. Another potential problem arises from the fact that panchromatic and multispectral images are often taken in different seasons of the year. In image fusion, it is desirable to minimize the color distortion since this ensures that features separable in the original multispectral image are still separable in the fused image.

Other terms with similar meanings to image fusion that can be found in the literature include image pan-sharpening, image merging, image combination, image synergy, and image integration. Data fusion is another term related to image fusion, but it has a broader meaning than image fusion.

Yangrong Ling

See also Image Enhancement; Image Processing; Remote Sensing

Further Readings


Image interpretation is the process used in remote sensing to extract meaningful information from photographic and digital images taken of the Earth’s surface and atmosphere. The goal is to identify, count, measure, and classify geographic objects or features in the landscape as they are represented by single images or to infer physical geographic processes from two or more images. Whether these objects are individual trees, clusters of trees, or a whole forest or whether the objects are buildings, neighborhoods, or a complete town depends on the spatial resolution of the remote sensor. Similarly, whether the tree is deciduous or coniferous or whether the building is a house or a store partly depends on the spectral resolution of the remote sensor. Spatial, spectral (and radiometric, referring to gray levels) resolutions refer to the specific designs of the optical-based or pulse-based sensors used in remote sensing, where variations of these resolutions determine the geographic scale and level of detail and the quality of interpretability. For instance, the widely used U.S.-based Landsat Thematic Mapper series has sensors designed with spatial resolutions of 30 m (meters) and spectral resolutions of six or seven bands or channels (referring to energy wavelengths), which makes them ideal for applications where objects are no smaller than 30 m on the ground, while the more recent Ikonos sensors are capable of much more detailed applications where objects of approximately 4 or 1 m should be recognizable.

On close inspection, raw aerial photographs and digital images are found to be composed of intricate patterns of basic tones and textures. Figure 1 illustrates the image interpretation process where these patterns are converted into meaningful geographic information. Most image interpretation procedures require the interaction of human skill, experience, and knowledge, with support from rigorous, systematic computer calculations.

At this point, the interpretation process can follow one of two directions. First is the traditional visual approach used when handling aerial photographs, which involves the systematic search for clues in how target objects on the ground
appear on the photos by understanding the interplay of tone, texture, shadow, pattern, association, shape, size, and site (refer to basic texts such as Campbell, 2006, for detailed discussions of each). The manual approach is heavily dependent on overlapping photos taken along the flight path, which facilitate a three-dimensional (3D) perspective when viewed with stereoscopes. The 3D view aids in object recognition and further assists with the calculation of scale, horizontal distances, and vertical heights of objects.

The other approach to interpretation is the computer analysis of digital images, where a number of algorithms are designed to enhance, contrast, and classify target objects based on numeric multispectral similarities. One of the simplest techniques to help identify geographic features is to enhance the visual appearance of the digital image by stretching the brightness levels of the data model used to represent the image. Remembering that raw images replicate the typically homogeneous nature of reality in small areas, pixel values are clumped within narrow data ranges, rendering the identification of geographic features difficult. By stretching this narrow range across the full extent of the data model (i.e., 256 brightness levels for 8-bit words), enhancement methods, such as linear contrast or histogram equalization, are able to “illuminate” and reveal much more detail in the landscape. However, enhancements are for visual purposes only and do not alter pixel values. Alternatively, edge enhancement is a filtering technique that involves a moving window designed to attenuate the values of pixels representing boundaries between geographic objects. This should make the interpretation of objects and features a little easier, although the image remains numeric.

For complete interpretation, digital images are frequently segmented, or classified into thematic groups based on similar pixel values (Figure 1 is an example of the conversion of similar pixels into three thematic land covers). Classification is backed by a growing literature and includes a variety of deterministic and stochastic approaches that focus on clustering individual pixels (or even predicting subpixel proportions), an emphasis on neighborhoods of pixels, commonly divided into textural analysis and object-based discrimination, as well as the use of ancillary data from other sources. In all cases, classification is intended to produce user-friendly maps that determine the geographic extent of land cover types, such as forests, soils, built-up areas, and water bodies, as well as attempting to infer land use types, such as agricultural practices and residential habitation. Of course, visual skills and computer proficiency are interrelated and important in both the traditional manual and the computer approaches, to the point where the blurred
IMAGE PROCESSING

Image processing is the application of software to digital satellite or aerial imagery in an effort to enhance the imagery and/or highlight features with the intent to gather information about the landscape and its spatial patterns. A few examples of how geographers use image-processing techniques include analyzing land cover and land use, detecting changes to the landscape, updating existing maps, analyzing vegetation patterns, performing biophysical analysis, supporting siting analysis, and studying environmental hazards and disaster recovery. The results of image processing are often combined with geographic information system (GIS) software and data to provide enhanced analysis and problem-solving support.

Digital imagery is provided in raster format, as a matrix of numbers representing the amount of light reflectance as collected throughout various portions of the electromagnetic spectrum. Complex image-processing software routines are applied to the image with the ultimate goal of highlighting landscape patterns. Image-processing techniques may be divided into three general categories: image preprocessing, image enhancement, and image classification.

Image Preprocessing

Image preprocessing involves geometric correction, georeferencing and image registration, and radiometric correction. Geometric correction involves applying algorithms to the image that correct for the curvature of Earth and the motion of the sensor. Georeferencing involves establishing a geographic coordinate system or registering images to each other, which is required for precise overlay of ancillary digital data or other imagery. Radiometric correction is the process of ensuring the accuracy of the surface reflectance values as represented by the digital numbers in the image. Most often, this process includes correcting for atmospheric attenuation of light waves because of atmospheric constituents such as water, dust, or pollution. In addition, images may contain system errors such as random missing pixels, missing partial or complete lines, or a...
consistent striping. Often these detector errors can be improved on in that values can be assigned to the missing data based on the surrounding pixel values; however, nothing replaces the fact that the data were not collected in the first place.

**Image Enhancement**

Image enhancement is the largest of the three categories in terms of number of techniques, which range from basic contrast enhancement to more state-of-the-art techniques such as texture analysis. The end results of image enhancement techniques are an increase in the visual interpretability of the image or the creation of a new image data set that will be used in follow-up enhancement or classification processes. Matrix algebra concepts and related algorithms are applied to an image, operating on the individual bands or multiple bands that represent different portions of the electromagnetic spectrum. Example techniques include a ratio of spectral bands to highlight vegetation patterns or health; edge enhancement algorithms that denote large digital value changes indicating an “edge” or change in land cover; and statistical methods such as principal component analysis, which seeks to reduce the redundancy among the different spectral bands by compiling as much unique information from the multiple image bands into fewer new image layers.

**Change Detection**

Change detection is the process of determining changes in land cover across time. Depending on the subject under investigation, anniversary dates and phenological cycles should be considered. In addition, environmental issues such as atmospheric conditions and soil moisture must also be considered when selecting the imagery. Once the imagery is selected, each image must be preprocessed as noted above and a change detection method selected. Each image is then digitally analyzed in the same manner, which includes image classification, principal component analysis, or vegetation indices. The images are then processed through the change detection algorithm, and an accuracy assessment is performed on the results.

**Image Classification**

Creating a land use and/or land cover map may be described as the ultimate goal of image processing. Image classification involves clustering pixels with similar digital values into similar land cover categories that eventually portray patterns of land cover on the landscape. There are four general types of image classification: supervised, unsupervised, and fuzzy classifications, and hybrid approaches. Before any classification begins, a classification scheme must be selected; there are several well-established, standardized systems from which to choose.

Supervised classification involves selecting training samples of areas in the image that are representative of the various components that have been outlined in the selected classification system. These training samples can be of water, grass, trees, pavement, buildings, and so on. Or if vegetation is the focus, training samples may be selected that represent deciduous trees, coniferous trees, and various types of grasses based on spectral reflectance curves. These training samples are selected by digitally drawing on the image a point, line, or polygon that contains the land cover. These samples are used to “train” the computer as they are representative digital values of the land cover in question. The software will then cluster the various pixels together based on their similar digital values, making the assumption that numbers of the same value are the same land cover.

Unsupervised classification involves allowing the computer to cluster the digital numbers into groups of similar values, based on the assumption that similar values indicate similar land cover. The analyst only combines the clusters of similar land covers (if necessary).

Both supervised and unsupervised classifications are considered traditional “hard” classifications in that every pixel is placed into a discrete cluster or category. Fuzzy classifications are an attempt to address the heterogeneity of Earth’s landscape and the “fuzzy” boundaries that exists between various landscape phenomena. “Pure” pixels, representing a single land cover, may be rare in an image. Because of the pixel size, a pixel may represent multiple land covers within this spatial resolution represented on the ground. Add to this the continuous
nature of Earth’s surface, to include transitions between land covers; this is the mixed-pixel problem. Fuzzy classification operates on fuzzy set theory, in which classes are created that do not have established boundaries; membership in each class is defined by a value that ranges from 0 to 1 indicating degree of membership in the class. Fuzzy classification is similar to supervised classification in that training samples are collected; however, a mixture of pure and mixed training samples may be collected. Each pixel in the image is then placed into one of the categories based on their degree of membership, which may range from full membership at 100% (pure) to partial membership; a pixel may have partial membership in several categories. A membership matrix is computed that includes the grades of category membership for each pixel, which can then be translated into a proportion of land cover components for each pixel.

While no classification method is perfect in all situations, decisions regarding classification method must be determined on a case-by-case basis. Hybrid image classification options are user defined and combine the various classification methods in a way that is most advantageous to the user and the analysis situation. After all classification techniques are applied, clusters are named according to the selected land cover classification scheme and an accuracy assessment is conducted based on in situ data or information collected from a source of equal or higher spatial resolution. The resulting accuracy should have an overall accuracy of 85% or greater and/or a kappa coefficient value greater than .8 (80%).

Among the commercial off-the-shelf image processing software are Leica Geosystems’ ERDAS Imagine, PCI’s Geomatica, ER Mapper, and ENVI, while GIS packages such as ArcGIS, Idrisi, MapInfo GIS, GRASS GIS, and Intergraph’s GeoMedia perform some image-processing functions as well.

Lisa Keys-Matthews

See also Aerial Imagery: Data; Aerial Imagery: Interpretation; Image Enhancement; Image Fusion; Image Interpretation; Image Texture; Map Algebra; Remote Sensing

Further Readings


Image Registration

Image registration is the process of precisely overlaying two (or more) images of the same area through geometrically aligning common features (or control points) identified in the images. The images can be taken at different times, from different viewpoints, and/or by different sensors. The registered images can be used for different purposes, such as change detection if the images are taken at different times, digital elevation model generation or shape reconstruction when the images are collected from different viewpoints, information integration when the images are taken by different sensors, and image mosaicking when the images have overlapping areas.

Figure 1 shows an example of image mosaicking, where the features 1, 2, 3, 4, 5, 6 and 1’, 2’, 3’, 4’, 5’, 6’ are the common control points identified in the overlapping area of the images 1 and 2’. The overlapping area can be registered through the alignment (or overlay) of the common points.

Normally, image registration consists of four steps: (1) feature detection and extraction, (2) feature matching, (3) transformation function fitting, and (4) image transformation and image resampling. Each of the steps is explained in the following four sections.

Feature Detection and Extraction

For image registration, a sufficient number of control points (common features) are required to estimate an optimal geometric transformation between two images. The control points can be
selected manually or extracted automatically. They are, normally, any of the following features:

- Line intersections
- Points of locally maximum curvature (such as building corners)
- Gravity centers of closed boundary regions (such as centers of building roofs or traffic islands)
- Centers of windows having locally maximum variance

The minimum number of control points required depends on the transformation function used. For example, when the conformal transformation function (Equations 1 and 2) is used, at least two control points are required. Because there are four unknowns \(a, b, c, \) and \(d\) in the transformation function, two control points are the minimum number to solve the equations and find the unknowns. More control points are usually required to achieve accurate solutions by least square approximation.

\[
x' = ax + by + c \quad (1)
\]
\[
y' = -bx + ay + d \quad (2)
\]

**Feature Matching**

After automated feature detection, numerous features can be extracted. However, many feature points may be extracted from one image but not from the other. Therefore, feature matching is necessary to find corresponding points (common features) in both images. The feature matching usually starts from one feature point on one image and then searches for the corresponding point on the other image.

Basically, there are two kinds of feature matching approaches: (1) area-based methods and (2) feature-based methods. In area-based methods, cross-correlation is often used as a similarity measure to find the corresponding point on the other image. In feature-based methods, the sum of squared differences is usually used to identify the corresponding point.

**Transformation Function Selection and Fitting**

Transformation function is used to model the geometric relationship between two images. A transformation function should take the possible geometric distortion between two images into consideration. There are two categories of possible distortions:

1. Global distortion
2. Local distortion

Different distortions need different transformation functions to overcome the distortion between two images.

- If there is no distortion but only rotation and translation difference between two images, a rigid transformation function can be used, such as conformal transformation function (Equations 1 and 2).
- For global distortion, many transformation functions can be used, such as affine, projective, and polynomial transformations.
- If local distortion is present, a more complicated transformation function is required, such as piecewise affine, piecewise polynomial, elastic, and radial basis functions.
After the transformation function has been selected, the unknown coefficients of the function, such as \(a\), \(b\), \(c\), and \(d\) in Equations 1 and 2, can be calculated according to the control points. One image can then be transformed to precisely overlay the other image, in which the pixels of the image being transformed need to be resampled.

In the transformation, usually, the pixel position \((x, y)\) in the target image (i.e., the image after the transformation) is transformed into its corresponding position \((x', y')\) in the image before the transformation. The gray value of the pixel \((x, y)\) is then determined by pixel resampling in the image before the transformation according to the pixel gray values around the position \((x', y')\) (Figure 2).

For image resampling, three interpolation methods can be used:

- Nearest-neighbor interpolation
- Bilinear interpolation
- Cubic interpolation

If the nearest-neighbor method is used, the gray value of the point \((x', y')\) will be the value of the nearest pixel—that is, Gray Value 3 in Figure 2. For the bilinear method, the gray value of the point \((x', y')\) will be determined by the four pixels with the values of 1, 2, 3, and 4. For the cubic method, the 16 pixels around the point \((x', y')\) will be used to calculate the gray value for \((x', y')\).

_Yun Zhang and Zhen Xiong_

**Further Readings**


Image texture refers to the subtle spectral differences present in digital or analog images and is defined as the spatial variation in pixel intensities or brightness values. The two most common ways to compute image texture are through first-order or second-order gray-level statistics. First-order texture statistics of local areas can be computed for means, standard deviation, and variance, among others. When computing these values, a moving window (e.g., a \(3 \times 3\) pixel window) computes the mean (or one of the other statistics), which is then assigned to the center pixel. For example, a \(3 \times 3\) moving window can be used to calculate the standard deviation for the center pixel. This process would help determine the pixel areas that have the most standard deviation (e.g., spectral differences) and would amplify edges within the image. This kind of information is usually not readily apparent when simply visually examining the image.
Second-order image texture measures represent a higher-order set of image texture information. These measures are based on spectral value spatial dependency gray level co-occurrence matrices (GLCM), which contain information about pixels and their neighbors at fixed orientations and distances. The GLCM-derived texture measurements have been widely adopted by the remote-sensing community, and typical measures that can be used to extract useful textural information are angular single moment, correlation, entropy, and homogeneity. Jensen and Gatrell (2005) demonstrated that image texture homogeneity was positively correlated with socioeconomic and population variables.

Most remote-sensing/image-processing software packages contain algorithms to measure both first- and second-order image texture. These algorithms usually allow the user to control many parameters. Some of the parameters that the user will probably control when computing image texture are the kind of image texture to measure (standard deviation, homogeneity, and so on), spectral band (e.g., near-infrared band), neighborhood pixel window size (e.g., 3 × 3, 5 × 5, or 7 × 7, although larger windows may be selected), and quantization level of the output texture image (8 bit, 12 bit, etc.). It is often necessary to experiment with these parameters until an optimum solution is found.

Image-processing algorithms, such as most forms of supervised and unsupervised classification, are usually single-pixel operations that do not consider image texture information in the classification process. However, sometimes researchers compute texture images and then incorporate them into the classification process as additional bands or as variance thresholds that define clusters (see Lillesand, Kiefer, & Chipman, 2004). In addition, recently, new image classification algorithms, such as feature extraction and other object-oriented methods, have begun to incorporate texture directly into the image classification process.

Ryan R. Jensen

See also Aerial Imagery: Data; Aerial Imagery: Interpretation; Image Interpretation
derivation of their spatial distribution (e.g., mapping), and finally their evolution over time (multitemporal analysis).

More than 300 yrs. (years) ago, in 1704, Sir Isaac Newton published his *Treatise of Light*, which presented the concept of dispersion of light. He demonstrated that white light could be split up into its component colors by means of a prism and found that each pure color is characterized by a specific refrangibility. Newton’s corpuscular theory was gradually succeeded over time by the wave theory. Consequently, the substantial summary of past experiences performed by James Maxwell in 1873 resulted in his equations of electromagnetic waves. But it was not until the 19th century that the quantitative measurement of dispersed light was recognized and standardized.

A major contribution was Joseph von Fraunhofer’s discovery of the dark lines in the solar spectrum in the early 1800s and their interpretation as absorption lines on the basis of experiments by Robert Bunsen and Gustav Kirchhoff in the mid 1800s. The term *spectroscopy* was first used in the late 19th century and provides the empirical foundations for atomic and molecular physics. Significant achievements in imaging spectroscopy are attributed to airborne instruments, particularly arising in the early 1980s and 1990s. However, it was not until 1999 that the first imaging spectrometer was launched in space (the National Aeronautics and Space Administration’s Moderate-Resolution Imaging Spectroradiometer, or MODIS).

Michael E. Schaepman

See also National Aeronautics and Space Administration (NASA); Remote Sensing; Spectral Characteristics of Terrestrial Surfaces; Spectral Resolution; Spectral Transformations

**Further Readings**


Immigration or international migration is one of the most significant and contested forms of spatial mobility of population in the 21st century. Its most basic definition is migration of a person or group of persons across a national boundary with the intent to stay. Migrations from culture regions of origin to regions of residence and control by members of other ethnic groups have occurred for millennia, but immigration as it is understood today is a relatively recent spatial phenomenon. Immigration, as defined above, assumes two requisite conditions: first, that political states have internationally recognized boundaries, and second, that political states have the sovereign right to determine who can cross those boundaries, particularly with the intent to stay. From the late 19th through the mid 20th century, for example, most of the African continent went through a spatial transformation from traditional settlement regions to colonization by European powers to independence with political borders approximating the colonial borders, ultimately imposing the status of “immigrant” to migrants who had maintained migration patterns that predated the borders. The same would be true of the former colonial regions of Asia (see Figure 1). In the Western Hemisphere, “colonists” came from a variety of countries, but new migrants were not considered “immigrants” until after each country gained its independence. Similarly, immigration defined the dominant populations and cultures of Australia and New Zealand.
Figure 1  Colonial migrations, 1500–1914, reflect the spatial reconfigurations of populations during centuries of European domination

Source: Based on Philip’s Atlas of World History, 2005. Map copyright Philip’s, a division of Octopus Publishing Group Ltd.
A variety of terms are used to refer to immigrants, depending on the context. An immigrant enters a country with the intent to stay, whereas the same migrant is an emigrant from his or her country of origin. Migrations can be free, or volitional, whereby the migrants freely make the choice to immigrate to a new country, or they can be forced, in that the decision to emigrate is imposed on migrants. This latter situation can encompass a variety of migration contexts. The global slave trade has historically accounted for the largest proportion of forced migrations, but persons displaced by wars and natural disasters account for a growing number of international migrants. In a contemporary context, immigrants are also considered documented, having entered with the authorization of the host country; undocumented, having entered without such authorization; or guest workers, having entered with authorization to work but not to become permanent residents or citizens of the host country. While most countries require some form of authorization or entry visa for lawful entry, whether for a shorter period of time as a tourist, a student, or temporary laborer or permanently as an immigrant, some countries also require exit visas, or permits for their citizens to leave the country.

As with any migration, immigration involves push and pull factors that fall into three interrelated categories—economic, political, and environmental. The most common reason for immigration is to improve one’s economic situation. A migrant goes where he or she hopes to
earn more than what can be earned at home. Such migrants can range from unskilled laborers to educated professionals. Many professionals from developing regions immigrate to developed countries to gain an income commensurate with their education, something that would be less likely in their home countries. Skilled, semi-skilled, and unskilled laborers migrate to fill labor niches created by changes in the economic or demographic structure of the destination country. For example, declining birth rates in European countries have resulted in the recruitment of labor migrants, often categorized as guest workers, to meet labor demands. Historically, Europe was a “migrant-sending” region, but in recent decades, European countries have had to face the need for writing immigration laws and for developing means to incorporate immigrants into their societies.

An economic migrant’s intent to stay may not be permanent. It may be just long enough to achieve an economic goal, such as a better house and economic freedom at home or paying for the education of his or her children. Thus, once the economic goal is achieved, the migrant may choose to return to the community of origin. While this type of “sojourner” international migration is nothing new, contemporary transportation and communication technology have increased the ease with which migrants can remain connected to family members in their community of origin. This allows for the establishment of a transnational household, where one or more members of the household lives and works in another country and remits earnings to the home community.

Political migrants leave a situation of war, oppression, persecution, or a well-founded fear of persecution in pursuit of freedom and safety. Since World War II, such migrants are classified either as political refugees or as seeking political asylum. In 1951, the United Nations drafted a definition and protocol for designating such migrants as refugees and for their treatment by countries where they seek asylum. Environmental migrants are displaced by such an extreme environmental disaster that they need to leave their country. An example of this type is the 1995 eruption of the Soufriere Hills volcano in Montserrat, a British overseas territory in the Caribbean, destroying the capital city of Plymouth and much of the surrounding territory and displacing two thirds of the island’s population.

Countries differ in their laws concerning the incorporation of immigrants as full members of their society. Rights of citizenship can be claimed by *jus sanguinis*, the right of blood, descending from the dominant ethnic group of the country; by *jus soli*, citizenship by birth in that country; or by *naturalization*, the conference of the rights of citizenship to an immigrant who has met the requirements outlined by the host country. As a country built on immigration, the United States passed naturalization laws very early in its history and recognizes *jus soli* for children of immigrants. In recent decades, due to significant increases in immigrants and guest workers, several European countries, including Germany, whose citizenship laws were historically based on *jus sanguinis*, have passed laws allowing immigrants, guest workers, and refugees granted political asylum the right to become citizens. However, there are still many countries worldwide that permit immigrants to enter but have not yet developed a process by which they can become citizens.

Ines M. Miyares

See also Citizenship; Migration; Population Geography; Refugees; Transnationalism

Further Readings


Imperialism is the process of forcibly expanding state authority over autonomous foreign territory by means of military conquest. More broadly, imperialism is the complex of practices through which one population establishes and maintains
instrumental control over the spaces, resources, and everyday lives of another. Imperialism is also the ideology through which a population is persuaded to support its domination of another and persuades that other to accept such domination.

There is no single and authoritative definition of empire, and it could even be claimed that any attempt to assert such a definition would itself be an imperializing act. Despite this, differing conceptions of imperialism and its root cognate—empire—do converge on certain principal geopolitical characteristics. Most broadly, imperialism entails the usurpation by an alien power of another’s territorial autarchy. This usurpation commonly takes the form of conquest by force, albeit to varying degrees depending on the place and time. The specifics of alien rule are highly contingent on the cultural practices and material needs of both the rulers and those they rule, yielding multiple, varied, and complex “imperial regimes of rule.” One very general illustration of this would be the predilection of European empires for acquiring territory, as contrasted with southeast Asian empires’ focus on the capture and mass relocation of populations. Furthermore, within the European empires there are significant differences between those beholden to monarchical versus republican models of internal governance or between those established chiefly through state military exercises versus those outsourced to private adventurers and mercantile enterprises.

Variations notwithstanding, imperialism can be understood through the world-systems concept of intertwined core and periphery regions, according to which global wealth is concentrated in core countries, while countries in the periphery (such as most of those in the global South today) do not benefit from this wealth. Core regions, and their metropolitan centers in particular, are greatly enriched through the expropriation of wealth from subjugated peripheries. It may even be argued that this asymmetrical core-periphery relationship is the central dynamic of imperialism through which empires are formed, expanded, and maintained by means of forcible exploitation of ever more distant markets and labor forces. It is also debatable, however, whether this explanation is as readily applicable to empires based outside Western Europe during the latter half of the second millennium.

In its constitution of sharply differentiated and dependent core-periphery relations, imperialism is inextricably conjoined with colonialism. The tightness with which the two are coupled, however, is again highly variable and open to debate. Most narrowly defined, and hearkening back to classical Greek city-states and the agricultural coloniae of Imperial Rome, a colony is an imperial possession established on empty (or, more commonly, forcibly emptied) peripheral territory that is occupied by settlers from the core and subject to a more or less direct imperial rule from the core’s metropolitan center. This definition, however, tends to underemphasize other, equally significant types of imperial territorial possessions in which preexisting populations are too sizable or well entrenched to be removed prior to resettlement. Such possessions tend instead to be administered by co-opted indigenous intermediaries overseen by functionaries imported from the imperial core, commonly with the intent of gradually absorbing the conquered population into the empire. Furthermore, the diverse spatial manifestations of different empires complicate the definition and identification of colonies. In the case of dispersed empires predicated on a distinct homeland and far-flung conquests, imperial possessions can be more plainly evident as colonies by virtue of their territorial discontinuity. But such recognition can be much more equivocal in the case of peripheral territories held by contiguous empires characterized not by detached possessions but by successive waves of accretive growth just over their own frontiers. Finally, imperialism in practice includes both the resettlement of some core personnel within all its subordinated peripheries and, barring out-and-out genocide, the continued exploitation of expunged populations. Thus, while colonization through dispossession is inherently an on-the-ground practice of imperialism, it is not a necessary one—imperial standing does not depend on possession of colonies in the strictest, narrowly defined sense of the term. Rather, empires deploy in varied combinations a spectrum of colonizing practices that range from the most direct forms of military occupation to more subtle insinuations of hegemonic influence, all inflected by local conditions in targeted peripheries and attenuated by the exercise of foreign rule over increasing distances.
Imperialism thus entails that ever more distant and distinct peoples will be subsumed within the boundaries of any given empire. Over time, this process tacitly encourages migration to the metropolitan cores and across the empire along the same routes initially established to logistically expedite peripheral occupation and extraction. Therefore, over the course of their developmental trajectories, all empires become inherently multicultural. As an ideology, imperialism facilitates social cohesion and continued expansion under such conditions. Working through media such as religious artifacts and their allied rituals, literary and topical communications, popular entertainments, and public commemorations, the ideology of imperialism effects a colonization of the mind whereby empire building is valorized and the conquered are given incentive to embrace, and even try to pass as, their conquerors. Thus, even empires without clearly determinable colonies strive to colonize the most intimate terrain, that is, their subjects’ psyches. The inclusivity of imperial multiculturalism, however, is also heavily disciplined by the state’s differential and strategically selective extension of suffrage rights. A strong incentive to adopt the cultural practices of, and even identify with, the imperial core is therefore frustrated by the establishment of elaborate social hierarchies that restrict the extent to which different subject peoples may assimilate into imperial society. Some peoples may never be permitted to rise any higher than the rank of the subaltern, whereas others may be regarded as too alien to rise at all no matter how well they mask themselves in the likeness of the conqueror.

The capacity of imperialism to establish and promulgate cultural hegemony, while delimiting who is considered fit to participate and to what degree in that hegemony, operates not just within empires but between them as well. By way of example, the military, economic, legal, infrastructural, architectural, and even sartorial reforms instituted in times and places as far apart as tsarist Russia, Rama V’s Siam, the Ottoman Empire, or late-19th-century Japan all reveal a consistent propensity among the then-waning and aspiring empires alike: self-conscious emulation of the practices of Western Europe’s rising imperial powers, as much to stave off being conquered by those powers as to pass as one and reap similar rewards. Imperial triumphs thus work both to absorb populations internal to empires and to entrain external populations far beyond the territory of the empire and its prospective conquests.

In its expansive influence, imperialism produces a global space divided into a ranked order of triumphal cores with peripheral dependencies. Furthermore, it simultaneously projects this mapping onto time. The peripheral is discursively conflated with the traditional and the backward and denigrated in juxtaposition with the core’s presumptive forward-looking modernity. The everyday life practices of people in the peripheries thus become holdovers of a mythologized past, and imperialism takes penultimate form as civilization’s solemn duty to progressively eradicate primordial savagery for the alleged good of the conqueror and the conquered alike. This is not the case for all times and places—empires founded by nomadic pastoralists like the Mongols or Osmanli Turks, for instance, tended to see empire less as a base for the export of civilization than a crossroad at which civilizations might best be collected and cherry-picked. But as a guiding geopolitical dynamic of the latter half of the second millennium, especially its terminal two centuries, imperialism colonized space itself and, through it, both time and consciousness. Indeed, treatises from the late 19th and early 20th centuries go so far as to assume tacitly “the empire” as a natural increment of geographical scale, situated firmly and irremovably between “the nation” and “the world.”

Of course, it has been proven empirically over time that the empire is far less an inevitable and inextricable scalar metric than had been previously assumed. Every empire to date has succumbed to imperial overreach, the invariably fatal penchant for conquering more territory than can be ultimately held. And over the course of two World Wars and a prolonged, lingering third (the “Third World” War, as Mexico’s Zapatista insurgents christened the Cold War), the larger global system of de jure imperialism itself suffered similar collapse. Extant empires ripped one another apart, all the while attempting to salvage themselves as repackaged commonwealths and coprosperity spheres. Concurrent with this process, subjugated peoples took up the task of liberating themselves as newly minted nations, more often than not following
the prescription to vomit up the colonizer—and by means of violence, if necessary. Ironically, such programs of national liberation were often aided and abetted, or even sown outright, by adjacent empires seeking to deploy nationality as a tool for destabilizing their competition.

It can be argued that in a decolonized and nationally reformulated global arena, blunt projections of imperial power can no longer be legitimized. Rather, a different sort of domination is necessary, one attained through the enactment of “soft power” that persuades others to cooperate willingly with a hegemon’s agenda. Past empires, however, have been no strangers to persuasion, to indirect rule, and to the dissemination of beliefs that domination will serve the best interests of the dominated. Nor does hegemonic soft power remain so soft—current hegemons have demonstrated a growing propensity to assert “unipolar preponderance” through massive shows of force against uncooperative foreign states. Hegemonic soft power, then, may be less a kinder, gentler new technique for dominance in a more polite postcolonial age than a temporary shift of emphasis within an arsenal of previously well-established imperial practices. This suspicion, in turn, has resulted in a growing body of literature examining the imperialist characteristics of self-declaredly nonimperialist, or even anti-imperialist, state formations such as the Union of Soviet Socialist Republics, the United States of America, the European Union, or the People’s Republic of China. More radically, it has been claimed that empire has taken on a new and largely despatialized form, enacted via globally diffuse networks of electronically linked state functionaries, business elites, and conjoined transnational institutions such as the World Trade Organization and the World Bank. Such claims for aspatiality, however, must contend with the persistent financial, technological, mass-cultural, and military preeminence of core regions and their long-established metropolitan centers in configurations substantially similar to those of a century ago. Empires do indeed rise and fall, but imperialism continues to prove far more durable in its self-servingly opportunistic ordering of space, time, and consciousness.

Imperialism, then, is something that must be defined multiply and flexibly (although not so open-endedly that, in its pervasiveness, it ends up meaning both everything and nothing). It is the more or less involuntary absorption of populations under expanding alien rule, the continued domination at a distance of the spaces and conditions of other’s everyday lives, the extraction and exportation of material resources from subjugated peripheries to conquering cores, and the means through which these programs are legitimized. Imperialism is all these things in varying and complex articulations, at different times and in different places, the here and now included.

Steven Flusty

See also Antiglobalization; Colonialism; Decolonization; Geopolitics; Neocolonialism; Neoliberalism; Orientalism; Race and Empire; Resistance, Geographies of; World-Systems Theory

Further Readings


Impermeable Surfaces

Impermeable surfaces come in two types: (1) anthropogenic ones and (2) those produced by natural processes. When most people use this term, they are especially concerned with the
anthropogenic types of impermeable surfaces that inhibit or prevent ready infiltration of water into the substrate, with the result that the volumes and velocities of overland flow of water increase and floods result.

Urbanization of watersheds commonly increases production of impermeable surfaces through the introduction of buildings, roads, paved parking lots, and various asphalt construction layers. Where impermeable surfaces are introduced into a watershed, especially if they are formed in later times after bridges and other structures have already been built downstream, there is then an increased propensity for even larger flash floods downstream, which the older bridges will not handle. This increased “flashiness,” as the result of construction of new impermeable surfaces upstream, often goes unrecognized in flood-control construction because the surfaces are spatially and temporally scattered. A further problem resulting from construction of impermeable surfaces is the increased pollution of nearby rivers, lakes, bays, and estuaries. The newly accelerated or channelized overland flow carries with it much of the animal and human wastes that would normally be spread more slowly into the soil and thereby degraded in the processes of infiltration. In some places, the introduction of concrete paving stones or brick and cobblestone pavers makes it somewhat more permeable and allows greater infiltration because of the common introduction of sand in the joints between the blocks, although they still provide the desired firm surface for bearing traffic.

Natural varieties of impermeable surfaces are certain forms of eroded or bare bedrock that is relatively unfractured, which thereby prevents water infiltration. While many kinds of lava flows are fairly impermeable when they are first extruded, later cooling can result in fractures that do allow some water to infiltrate into them. An unusual group of impermeable surfaces that can be entirely natural but that are commonly exacerbated or accelerated by humans, are the various kinds of duricrusts (hard, thin layers on the surface of the soil) that form in different climatic regimes. In the humid tropics, natural subsoil accumulations of iron and aluminum sequioxides form in the subsoil from long-term weathering of bedrock into soft, clay-rich saprolites that can be subsequently exposed by natural or human-caused soil erosion and hardened into rigid fersialitic (iron, silica, aluminum) crusts. Those lateritic duricrusts that become exposed on the surface can be quite impermeable and commonly resemble a thick and even shiny layer of iron (iron shield or cuirasse) on the ground. In more arid regions, the cementation can be rich in calcium carbonate so that impermeable calcrete or caliche crusts and caprocks result. Where precipitated from a lake that has dried up through climate change, as has happened at the Great Salt Lake and Bonneville Salt Flats in Utah or Death Valley in California, the high concentration of salt in the evaporating waters can result in an impermeable layer of rock salt (salcrete) or gypsum (gypcrete) on the surface. In arid parts of Australia, silcretes bearing opal are relatively impermeable concentrations of long-term weathering and siliceous cementation.

John F. Shroder

See also Flash Floods; Floods; Nonpoint Sources of Pollution

Further Readings


Import Substitution Industrialization

Import substitution industrialization (ISI) is an approach to national development based on the notion that conditions in the developing world vary markedly from conditions in the developed world. In an attempt to reconcile some of these
differences, ISI relies on strong state intervention to protect developing industries from competition with foreign firms. This protection is most commonly in the form of high tariffs on imported goods. After the initial period of protection, the state then is supposed to remove protections to allow the now established industries to compete with foreign firms. The result of a successful implementation of ISI should be the development of national value-added industries. These industries in turn lead to a reduction in the country’s dependence on foreign markets, which is symptomatic of economies based on the export of raw goods. ISI was most popular between the 1930s and the 1980s in Latin America, though some countries in Asia and Africa also adopted it in the 1950s.

### Theoretical Roots and Background

ISI is partially based on the idea of the “infant industry” put forth by Friedrich List, a 19th-century German economist. List argued that, contrary to what free-market proponents such as Adam Smith and his followers were saying, state intervention was needed in less developed countries to protect their fledgling industries from competition with much further developed industries from other countries such as Britain. Once the infant firms had caught up with the mature foreign firms, they could then participate in unregulated competition in the world market. List’s ideas represented an important departure from the neoclassical model of economic development. They have influenced and continue to influence several popular state-led development models since the 19th century, including ISI. Another important influence for ISI is the Singer-Prebisch thesis, which calls for a move away from exporting raw materials and toward exporting value-added goods to improve a country’s position in the global market.

Both the infant industry model (IIM) and ISI, two of the main development models based on the ideas of List, have in common an emphasis on developing human capital and local markets and an initial reliance on capital raised by the state to start an industry. However, they have two important differences. First, the IIM favors selective protection of industries most likely to succeed, while ISI calls for indiscriminate protection of local industries. Second, IIM favors building export industries, while ISI often relies on industries that will satisfy local demand.

### ISI in Practice

Application of ISI in practice began in Latin America in the 1930s, during the Great Depression. The global market for primary goods from Latin America plummeted as a result of the Depression, and later, as a result of the outbreak of World War II. Without a market for their primary goods, Latin American countries were unable to import manufactured goods and realized that they would need to develop their own industries to satisfy local demand. They began to build their industries by focusing on domestic markets and regional trading rather than on the volatile world market. Evidence of increasing state involvement in industry at this time can be seen, for example, in the nationalization of foreign-owned railways and oil companies in Mexico. Further development and support of the ISI approach came from the structuralist ideas underlying the United Nations Economic Commission for Latin America (ECLA). Some of the key proponents and theorists for this approach included ECLA Executive Secretary Raúl Prebisch and the Brazilian economist Celso Furtado.

ISI-based policies enjoyed their greatest popularity in Latin America during the 1960s and 1970s in spite of already obvious problems related to balance of payments deficits from the heavy borrowing involved in ISI policies. Evidence of these policies include the popularity of trading blocs in Latin America to protect and promote regional trade on more favorable terms than trade on the world market. These trading blocs were thought to be necessary for many of the smaller Latin American countries to have access to sufficiently large markets for their goods.

In 1960, Costa Rica, Guatemala, and Nicaragua created the Central American Common Market (CACM) to promote development of industries in Central America. Under this agreement, consumer goods were the most highly taxed because these goods were the focus of ISI policies for promoting domestic production in these countries. All goods entering the CACM zone were taxed at
the same rate on entry under a common tariff barrier, and some goods, including many industrial ones, were traded tariff-free within the CACM zone. The Latin American Free Trade Association, founded in the 1960s and now known as the Latin American Integration Association, is another example of these trading blocs.

Other evidence of ISI at work in Latin America at this time includes massive state-funded infrastructure projects in Brazil, Argentina, and Mexico, meant to catapult these countries into the realm of highly developed countries. Unfortunately, the capital for these projects came from loans, and as oil prices increased and raw material prices decreased, balance of payments deficits in many Latin American countries grew. The global recession in the 1970s and early 1980s caused interest rates to increase and brought to a halt many of these state-funded development projects and ultimately led to abandonment of many ISI development strategies in Latin America.

Notable examples of ISI in practice in countries outside Latin America include South Korea, Taiwan, India, and China. Many countries outside Latin America that adopted ISI deemphasized the inward-looking elements of ISI and instead focused on maintaining high tariff barriers while protecting and promoting export industries such as steel and petrochemicals.

**Results of the ISI Approach**

The major advantages of ISI approaches include promotion of domestic employment in higher-skilled jobs; shorter travel distances for goods from their place of production to their place of consumption, resulting in reduced fuel consumption and pollution; and the possibility for countries to resist the impact of global economic shocks on national economies by limiting their dependence on global markets. The success of ISI in achieving these advantages differed with each situation, and it is difficult to think of one country that truly achieved success following an ISI approach to development. India and China are often cited as examples of successful ISI implementation, but India’s record of growth under ISI was only mediocre and China’s rapid economic growth started after it began liberalizing its markets in the late 1970s. In Latin America, ISI has been declared both a success and a failure. For example, Brazil and Mexico’s levels of economic growth were relatively high between 1950 and 1980 when ISI approaches were still in use, but their national production remained much smaller than that of either Britain or the United States.

*Lisa Rausch*

*See also* Dependency Theory; Development Theory; Export-Led Development; Industrialization; Trade; Underdevelopment; World-Systems Theory

**Further Readings**


**Incubator Zones**

Incubator zones are designed to encourage entrepreneurship by providing business support services and technical assistance. They primarily cater to start-up businesses or other businesses that are not well established. The exact services that are provided by incubator zones vary, but they generally provide a variety of business support services. Businesses are generally required to apply in order to become part of an incubator program. Acceptance is based on a variety of factors, including the nature of the business and the quality of the potential entrepreneur’s business plan.

**History of Incubator Zones**

According to the National Business Incubation Association, the first incubator zone in the United States was the Batavia Industrial Center. It opened in 1959 in Batavia, New York. By the late 1970s, incubator zones became more common in the
United States, especially in the Northeast, where they were seen as a means to help bring about the revitalization of communities that had been hit hard by deindustrialization. The growth of incubator zones accelerated rapidly in the 1980s as many communities recognized the value of promoting small-business development as a means of promoting economic growth. Incubator zones have spread throughout the world. The National Business Incubation Association estimates that there are currently about 5,000 incubator zones around the world.

The U.S. Small Business Administration promoted the development of incubator zones in the mid 1980s. The Small Business Administration held several conferences and published several handbooks and a newsletter. Another important development in the growth of incubator zones in the United States was the creation, in 1982, by the Pennsylvania Legislature of the Ben Franklin Partnership Program, one of the first comprehensive manufacturing and technology agendas in the United States. Incubator zones were a key component of this program, which serves as a model for other programs around the United States.

**Services Provided by Incubator Zones**

The length of time that a business spends in an incubator zone varies, depending on a number of factors, including the nature of the business and the entrepreneur’s level of business acumen. In industries, such as biotechnology, that have relatively long research and development cycles, companies generally require more time in an incubator zone than service or manufacturing companies that can bring a product or service to market in a relatively short time. On average, companies spend a little less than 3 yrs. (years) in an incubator zone. Most incubator programs set benchmarks, such as staffing levels or revenues, to determine when companies are ready to leave an incubator zone.

Incubator zones provide a variety of services to start-up companies, but some of the most common services that they provide are management guidance, technical assistance, and consulting services. Many incubator zones provide additional resources, including access to suitable rental space, flexible lease terms, shared services, and assistance in securing the financing necessary to allow a company to grow.

Many incubator zones in the United States are affiliated with the National Business Incubation Association, a nonprofit organization whose primary mission is to provide training and to serve as a source of information on incubator management and tools to assist start-up businesses. In addition, the National Business Incubation Association conducts research, compiles statistical data, produces publications to disseminate best practices, and tracks relevant legislation.

**Role of Incubator Zones in Economic Development**

Incubator zones are sponsored by a variety of entities, including national or regional government, colleges, and universities, while others are private entities. They cater to a variety of industrial sectors, including technology, professional services, manufacturing, food processing, biotechnology, health care, the media, the arts, and fashion. Incubator zones are often part of a wider economic development strategy. Incubator zones provide a variety of economic and socioeconomic benefits, including creating new jobs and wealth, enhancing the entrepreneurial climate of a community, diversifying the local economy, accelerating the growth of industry, encouraging business ownership by women and minorities, helping to bring about community revitalization, and facilitating the transfer of knowledge from universities and large corporations. Incubator zones are created in a variety of settings, from rural areas to inner cities. Some examples of communities in the United States with incubator zones include Birmingham, Alabama; Columbus, Ohio; Troy, New York; Philadelphia; San Jose, California; and Atlanta. Incubator zones are found in many countries around the world, including Australia, China, Israel, South Korea, and the United Kingdom.

In addition to playing an important role in promoting economic development, incubator zones can play a particularly important role in helping research scientists bring potential new products to market. Most researchers lack significant business knowledge, and unfortunately that lack of
knowledge can prevent potentially significant new products from ever making it to the market. Incubator zones can help bridge this knowledge gap, making it possible to transform innovative ideas into marketable products.

Jared Wouters

See also Agglomeration Economies; Economic Geography; Industrial Districts; Innovation, Geography of; Learning Regions; Regional Economic Development; Technological Change, Geography of

Further Readings


INDIGENEITY

Developed over the past two decades, the term indigeneity has developed out of the contemporary global indigenous peoples’ movement. The term describes this evolving pan-indigenous movement and corresponding identity among peoples who, despite often considerable cultural divergence, share significant symmetries that have evolved from the common experiences of European colonialism. These similarities are founded in an ancestral birthright in the land, a common core of collective interests, and the shared experience of dispossession precipitated through the colonial projects perpetrated against their communities by colonial and neocolonial state administrations. The term is used not only to support the rights of indigenous peoples but also to recognize indigenous ways of knowing and the ethical codes evolved over thousands of years by indigenous communities.

Origin and Development of the Indigenous Peoples’ Movement

The history of the indigenous peoples’ movement is traced by many to the 1923 appeal by Deskaheh to the League of Nations on behalf of the Six Nations of the Iroquois Confederacy. Deskaheh, a traditional leader of the Cayuga, sought the support of the League in his claims against the Canadian government, who were imposing a tribal council system of administration on the Six Nations Grand River reserve. Despite his failure to address his petition, “The Redman’s Appeal for Justice,” before the League, Deskaheh did succeed in presenting his case before several ambassadors with the assistance of the mayor of Geneva and convinced these ambassadors to address these concerns directly with the Canadian government. Unfortunately, while he was in Geneva, the Canadian government succeeded in forcing a “democratically elected” government on the Six Nations reserve, and subsequently, Deskaheh lost his mandate.

Despite Deskaheh’s failure to have his nation recognized by and their case heard before the League, the recognition of the unique political status of indigenous peoples has nonetheless slowly developed in the international community for over the past 80 yrs. (years). The first significant recognition of the need for protecting indigenous peoples’ rights against the encompassing domination of state governments came in 1957, when the International Labour Organization (ILO) issued its “Indigenous and Tribal Populations Convention,” later updated in 1989 by a more strongly worded convention. Through these conventions, the ILO set in motion an evolving international legal framework that not only
recognizes the status of indigenous peoples as a unique category within international law but also recognizes that indigenous peoples require protection from the continuing colonial and neocolonial projects of state governments.

Following in the footsteps of the ILO, the United Nations (UN) began in 1982 to investigate the demands made by indigenous peoples for attention to their unique status within the international state system. While the UN had adamantly affirmed the sovereign rights of peoples colonized by European powers throughout Africa, Asia, and the Pacific to decolonization and self-determination through the “Declaration on the Granting of Independence to Colonial Countries and Peoples of 1960,” the organization had made no move toward addressing the situation of peoples whose lands had been subsumed into settler states, predominately in the Americas and the South Pacific, or those peoples who remained disenfranchised minorities within the newly decolonized states of Africa and Asia. Beginning with the Martinez-Cobo study in 1983, the UN started down a path whose ultimate outcome has been the recognition of indigenous peoples’ self-determining rights within an organizational structure that had previously failed to acknowledge any self-determining authority other than through internationally recognized states. Following the recommendation of the Martinez-Cobo study, the UN created the Working Group on Indigenous People under the Office of the UN High Commissioner on Human Rights. The primary aims of this working group were twofold: first, to create a permanent forum for indigenous peoples within the UN system and, second, to draft a Declaration on Indigenous Peoples Rights with the hope that this instrument would provide the next step in further defining the evolving international legal framework for indigenous peoples’ rights. With the creation of the UN Permanent Forum on Indigenous Issues in 2000 and the approval by the UN Generally Assembly of the Declaration on Indigenous Peoples’ Rights in 2007, the international indigenous peoples’ movement has entered a new era.

**Definition and Goals**

The issue of defining which groups of peoples can and cannot be considered indigenous has been and continues to be a significant challenge for international fora. While the definitions created by a range of organizations and authors have varied, sometimes significantly over the past 50 yrs., recently a broad consensus has formed within the international political community. Four core principles have been agreed on in defining indigenous peoples: First, they generally live within, or maintain attachments to, geographically distinct territories; second, they tend to maintain distinct social, economic, and political institutions within their territories; third, they typically aspire to remain distinct culturally, geographically, and institutionally rather than assimilate fully into national society; and, fourth, they self-identify as indigenous or tribal. Central to the issue of definition is self-identification as an indigenous people.

It is within the political arena that indigenous peoples are voicing their sociopolitical, cultural, and economic aims. These political aims are significantly similar across the breadth of the global indigenous peoples’ movement. They are founded on securing a land base, protecting and controlling the natural resources of that land base, attaining a degree of political and legal authority over those territories, and securing the right to speak and maintain their ancestral languages, with freedom of cultural and religious expression.

While the political community has begun to close the definitional boundaries around specific groups, clearly defining particular groups as indigenous peoples while excluding others, the academic community continues to openly debate indigeneity. In an effort to achieve their political aims, indigenous peoples have, as have other groups struggling for the recognition of human rights, employed strategic essentialism. Unfortunately, the strategic performance of an essentialized cultural identity to secure political ends is a means that leaves the academic community, and many nonacademics, confused and troubled. Since 2003, an extensive debate concerning the indigenous peoples’ movement and the appropriateness of defining any group of people as indigenous has been held within the pages of *Current Anthropology* and other journals. Central to this argument has been the claim by groups of people who self-identify as indigenous to be the “first peoples” or “first nations” of particular territories. Current anthropological and archaeological thought holds
that *Homo sapiens sapiens* first evolved in Eastern Africa and migrated out to populate the planet beginning around 100,000 yrs. ago. Since most peoples are migrants to the landmasses in which they currently live, whether this migration occurred 50,000 or 200 yrs. ago, some argue that no group can claim indigeneity. Others argue that the impact of colonial contact has transformed nearly every human culture to the point that no group can claim an “authentic” indigenous identity. These arguments ignore or gloss over the realities of European colonialism, which created the first global world order and brought the cultural, political, and economic imperatives of Europe to every corner of the world. They also ignore the devastating effect of disease, warfare, and colonial “civilizing” projects on indigenous populations. Dealing with the political, moral, and ethical ramifications this colonization has wrought on the planet has been the work of international fora representing indigenous peoples over the past 80 yrs. The demands brought by indigenous peoples for a just reconciliation of the ongoing impacts of colonization are the central political aim of the international indigenous rights movement.

*Jay T. Johnson*

**Further Readings**


**INDIGENOUS AGRICULTURE**

Indigenous agriculture encompasses agricultural practices and techniques that are unique to a given culture and society and has evolved from place-bound tradition. In practice, it is often more diverse, complex, and risk-prone than both industrialized and green revolution agriculture. The concept may refer to the agricultural practices of groups that claim status as indigenous people, but it is not usually so restricted. While farmers often experiment and innovate, the invention of new agricultural implements and the domestication of new cultivars are not very common occurrences, and successful innovations are often diffused widely. “Indigenous” may thus refer more to local control over knowledge and technology than to origin. The debate on the virtues and relevance of indigenous agriculture focuses on the developing world and is related to a wider debate on indigenous knowledge and its relevance in development. There is also a question of how indigenous agriculture, which has not been the focus of science-based advances in agriculture, can be best assisted. Furthermore, there is considerable interest in indigenous agriculture as a basis for an alternative development that is environmentally sound, less dependent on external input, and locally controlled. While research has documented a range of practices and techniques, differing views on indigenous agriculture persist among scientists and peasant groups.

Under the dominant modernization paradigm, smallholder agricultural practice in the tropics is seen as traditional and static. Today, the objective is to transform or replace the practice of resource-poor “traditional agriculture” with “modern agriculture” through standardized green revolution packages of monoculture, including hybrid seed, agrochemicals, mechanization, and irrigation. In the transformation approach, this dichotomy is emphasized, and tradition in agriculture is seen mainly as a problem to be overcome through technology transfer. Resource poverty, and the lack of capital investment and inputs, leads to poor efficiency in agriculture, and the lack of innovation is seen as a key problem. The Green Revolution from the 1960s onward has led to substantial increases in the output of
rice and wheat, for instance, in India. However, criticisms have focused on environmental sustainability, resilience, increased dependence on inputs, and social impacts. The focus on increasing yield per acre for a few selected crops has resulted in significantly less research being carried out on other crops and on more complex and diverse farming systems.

An alternative outlook emerged in the 1980s, when indigenous agriculture was viewed more as an underused resource and less as an obstacle to rural development. Inspiration was drawn from cultural ecology and from agrarian populism. Paul Richards, drawing on research in West Africa, argued that cultivators’ reluctance to adopt modern scientific advice should not be viewed as a stubborn refusal to change but rather as an unwillingness to accept inappropriate methods. He argued that while technology transfer through dramatic modernization had a poor track record in the region, the most successful innovations in food crop production had indigenous roots. In cases where he found that scientific advice had often failed and peasant farmers were often successful, this was explained through a positive, inquisitive, and experimental approach on the part of the indigenous peasant rather than through an unchanging inherited knowledge base. The peasants were better able to estimate the simultaneous effect of several variables and...
to adopt and adapt technology selectively. D. Michael Warren, David Brokensha, and other researchers have sought to document and disseminate indigenous knowledge in agriculture as taxonomies, techniques, and farmers’ innovations in order to mobilize an underused resource in development. Under the “farmer first” paradigm, Robert Chambers and colleagues called for increased learning from smallholder practice in diverse and risk-prone resource-poor agriculture and a more creative interaction between scientists and farmers in the development of agriculture. This approach would involve a reversal of the learning process inherent in technology transfer to better serve the needs of complex, risk-prone, and diverse farming systems.

Indigenous agricultural practices may be extensive or intensive. An example of extensive cultivation is swidden cultivation, which relies on long fallow periods to regenerate soil nutrients. The practice can be efficient, but shortening cultivation intervals in response to population growth can be destructive. Intercropping or relay cropping with cereal, leguminous, and other crops is used as an alternative to crop rotation in arable cultivation. Examples of intensive methods include rainwater harvesting, which can reduce risk and increase productivity in semiarid environments. Furthermore, indigenous irrigation may include stream diversion, storage, and horizontal wells tapping into aquifers (*quaanat*), as well as more flexible strategies of flood cultivation in wetlands and spate irrigation, which relies on ephemeral streams. Another intensive practice is agroforestry; the integration of field crops with livestock and also trees for shade, mulch, and additional produce. Specific intensive field techniques exist, such as the raised field cultivation in wetlands in the area around Lake Titicaca in South America. One research objective relating to “indigenous agricultural knowledge” is to document, develop or rehabilitate, and disseminate such practices.

Anthony Bebbington argues that the emphasis on indigenous agricultural knowledge may be seen as voluntarist, ignoring how the state, the economy, and wider systems of social relationships affect peasant agency. He has described how indigenous farmers and their peasant organizations in Ecuador have sought to abandon organic farming and instead modernize production through, among other means, the increased use of agrochemical inputs in order to sustain their Indian identity and rural way of life. Thus, resistance to the modernization of indigenous agriculture is not necessarily a preferred strategy of indigenous people and other peasant communities.

Mattias Tagseth

See also Agriculture, Preindustrial; Agroforestry; Bush Fallow Farming; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Indigenous Water Management; Nomadism; Peasants, Peasantry; Shifting Cultivation

Further Readings


### INDIGENOUS AND COMMUNITY CONSERVED AREAS

Indigenous and community conserved areas (ICCAs) are natural and/or modified ecosystems containing significant biodiversity values, ecological services, and cultural values. ICCAs are voluntarily conserved by indigenous peoples and local communities (both sedentary and mobile), through customary laws or other effective means. This term has been used for convenience and
incorporates a wide range of phrases used to denote such sites, including biocultural heritage sites, indigenous protected areas, and locally managed marine areas, among others. The term is not meant to show disrespect to the legitimate demands of many indigenous populations to be called “peoples” instead of “communities” and to recognize their homelands as “territories” instead of “areas.” ICCAs are relatively new in conservation and environmental circles, having originated from work done on community-initiated conservation in India in the late 1990s (see the Khonoma Tragopan Sanctuary photo). But the sites and initiatives they denote are as old as human civilization itself and are in many ways the world’s oldest protected areas. These include sacred sites protected from all or most human uses other than once-a-year rituals, watershed forests conserved with only minimal subsistence use, wildlife populations left strictly alone for ethical reasons, and indigenous and mobile peoples’ territories managed to balance ecosystem protection and resource use.

Recognition of the reality and spread of ICCAs is recent—a result of a shift that took place in international conservation forums in the first few years of the new millennium. For over a century before this, it had been assumed that wildlife and biodiversity could best be conserved in designated protected areas managed by government bureaucracies, aided at best by scientists and conservation nongovernmental organizations (NGOs). This has now given way to the realization that there are a variety of other actors who can be
equally if not more capable—in particular, indigeneous peoples and other traditional local communities (hereafter called communities).

The Diversity of ICCAs

Community conservation initiatives are extremely diverse and can be classified or analyzed from several points of view:

- Their coverage of different kinds of ecosystems and wildlife species (encompassing the full range found on Earth)
- The objectives and motivations behind their establishment (including ethical, cultural, economic, and political reasons)
- Their origins (autochthonous by communities or triggered by outsiders)
- The institutions governing them (as different as the communities themselves, ranging from entire villages to youth clubs and women’s groups and specialized conservation groups)
- The various ecological and social impacts they have
- Their size (ranging from a tiny patch of forest or sea of less than 1 ha (hectare) to several million ha of rain forest, savanna, or mixed land uses).

ICCAs include the following geographies:

- Indigenous peoples’ territories managed for sustainable use, cultural values, or explicit conservation objectives (e.g., many indigenous protected areas in the Amazon and Australia)
- Terrestrial or marine territories over which mobile or nomadic communities have traditionally roamed, managing the resources through customary regulations and practices (e.g., the territories of the Qashqai in Iran and the Borana in Ethiopia and Kenya, both containing substantial wetland and wildlife values)
- Sacred spaces, ranging from tiny forest groves and wetlands to entire landscapes and seascapes, often left completely or largely free from human use (e.g., thousands of sacred groves in India and several sacred crocodile ponds in Mali)
- Resource catchment areas, from which communities derive their livelihoods or key ecosystem benefits, managed such that these benefits are sustained over time (e.g., community forests in many African and South Asian countries)
- Nesting or roosting sites, or other critical habitats of wild animals, conserved for ethical or other reasons explicitly oriented toward protecting these animals (e.g., dozens of waterfowl nesting wetlands in Southern India)
- Community forests managed by towns (e.g., several in North America)
- Landscapes with mosaics of natural and agricultural ecosystems, managed by farming communities or mixed rural-urban communities (e.g., the Potato Park in the Andean highlands of Peru, the rice terrace regions of the Philippines, or the protected landscapes of Spain and many other European countries)

Though extremely diverse, ICCAs display three essential characteristics: (1) the community (or communities) is the most important decision maker, even though other actors may play a role; (2) the community has one or more crucial links to the area and its species: cultural, spiritual, ecological, economic, and political; and (3) whatever the objectives of management may be, conservation is being achieved in varying degrees.

The Significance of ICCAs

The international conservation community has started paying much more attention to ICCAs, for several important reasons:

- They conserve or have the potential to conserve an enormous part of the Earth’s beleaguered biodiversity (see the Coron Island photo); indeed, though existing documentation is not adequate to judge their extent, they may cover an area as big as government-designated protected areas (which today amount to about 12% of the Earth’s terrestrial surface).
- They help or can help in providing connectivity across large landscapes and seascapes, which is crucial for migration of wildlife, livestock, and people and for genetic exchange.
**INDIGENOUS AND COMMUNITY CONSERVED AREAS**

They provide substantial environmental services, such as water and nutrition flows, soil protection, and others.

They provide enormous survival and economic benefits and important lessons on how to link nature conservation with livelihood security.

They are "natural" sites for cultural sustenance, displaying the varying ways in which humans have lived with and within nature; a great many are sites of spiritual significance, and in the case of many indigenous and mobile peoples, the land itself is akin to the temples and churches of mainstream religions.

They are often seamless landscapes of wild and agricultural or domesticated biodiversity, providing important ecological and cultural links between two crucial parts of human life that have in modern times become artificially compartmentalized and separated.

In many ways, ICCAs can become a crucial component of the human response to global climate change. They are effective ways of avoiding or mitigating climate impacts, by ensuring the continued protection of ecosystems. Equally valuable is their potential for adaptation, by providing corridors for ecosystem and species migration that will inevitably occur due to changing climatic conditions, and because their biological and cultural diversity contains the bases of resilience that communities everywhere will need.

ICCAs are not a panacea for all conservation and livelihood problems, nor should their growing profile imply that communities everywhere are conservation oriented. ICCAs have their own strengths, including locally adapted practices based on sophisticated knowledge, often strong institutions and customary law, and others. They also have their own weaknesses, including

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Coron Island, a biodiversity-rich coral island seascape managed under ancestral domain claim by the Tagbanwa indigenous people of the Philippines

*Source: Author.*
sometimes the neglect of species not considered important or local inequities that undermine the sustainability of the initiative. Increasingly, ICCAs face serious threats from inappropriate “development” and infrastructure activities such as mining, dams, and urbanization; the lack of tenurial security in countries where community rights and territories are not adequately recognized; the changing cultural norms, and other forces. These are greatly compounded by the lack of recognition of most ICCAs by state agencies and NGOs. Over the past few centuries of centralized rule and industrial exploitation of resources in such countries, their role has been seriously eroded.

Do ICCAs Have a Future?

If ICCAs are to remain or become a significant component of conservation and sustainability of human life, they need urgent recognition and support. Having understood this, the International Union for Conservation of Nature and the International Convention on Biological Diversity (through its Programme of Work on Protected Areas) have urged countries to consider ICCAs as crucial components of their conservation policies and practices. Some countries have started providing the legal and policy backing for this (with some, such as Australia and Colombia, having started several years ago), but most have a long way to go. Even where countries are beginning to recognize ICCAs, often it is done in top-down ways, with governments dictating to communities what kind of (rather homogeneous) management institutions should be established—a contradiction in terms!

Considerable innovation is needed in national and regional policies to support ICCAs, in particular to respect that they represent a crucial interface between ecological and cultural diversity and are at their core site specific, constantly evolving responses to the challenges and opportunities that communities find living with nature. Many need technical and financial support and social recognition; conversely, many may thrive under deliberate neglect since the most culturally sensitive communities may find even a bit of public exposure detrimental to their interests.

Ashish Kothari

See also Biodiversity; Biosphere Reserves; Community-Based Conservation; Environmental Services; Indigeneity; Indigenous Agriculture; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Reserves; Parks and Reserves; Patches and Corridors in Wildlife Conservation

Further Readings


INDIGENOUS CARTOGRAPHIES

Indigenous cartographies are the mapping practices, past and present, produced or conceptualized by indigenous peoples and informed by the aesthetics and sign systems of the societies from which they derive. They are as diverse as the peoples who practice them. In Mesoamerica, Mixtec lienzos depicted the genealogical histories of cities through place name symbols and pathways. In Siberia, Chukchi and Mansi navigational cartography is inscribed on bark or painted directly on trees along a route. Bozo cartography in West
Africa includes depictions of watersheds drawn on the ground as part of an annual ceremony. And in North America, Dine Navajo cartography includes the placement of rocks and cairns in lines in the landscape to mark the stages of stories.

**Characteristics of Indigenous Cartographies**

From this diversity, common characteristics emerge that reflect the common characteristics of indigenous knowledge systems generally. Indigenous cartographies are characterized by performativity, the inextricability of the spiritual from geographical experience and expression, an emphasis on storied place names, and the incorporation of physical landscape and community memory as a cartographic archive.

When viewed through nonindigenous eyes, it may be difficult to recognize some of those practices as mapping because they stand apart from Western or Euro-American expectations of how maps work and what maps should look like. For decades, this restricted vision limited nonindigenous awareness of such traditions to a few popular examples, such as the bone carvings of coastlines made by Inuit peoples and the tide charts created from sticks and shells by Marshall Island sailors for teaching traditional navigation techniques.

In the 1970s, largely through the works of G. Malcolm Lewis and Louis de Vorsey, building on the early work of Bruno Adler, a cartobibliographic record for American Indian mapmaking began to take shape in map history. This early work analyzed the accuracy of linear, Euclidean measure in Native maps in comparison with European maps. While this analysis qualified less measurably accurate examples as primitive, cognitive, or maplike, the revelation that some indigenous maps do contain such measurability overturned the perception that Native people had no concept or skills of distance measurement. The Columbian Encounter conferences and symposia of 1992, including the first traveling exhibition devoted to indigenous cartography, encouraged further scholarship, shifting attention to Native peoples’ contributions to colonial cartographies such as the Hudson’s Bay Company maps, the Lewis and Clark expedition, and the *relaciones geograficas* of New Spain. Through both archival study and visual analysis, scholars examined the unacknowledged processes by which Native cartographies were transformed into printed, European maps as part of the colonial project, driving the European printed map market while simultaneously erasing their own ancient geographies.

**Theoretical Perspectives**

These symposia coincided with, and were thus influenced and enriched by, the critical theoretical breakthroughs in geography during the late 1980s and early 1990s. Drawing on the work of Michel Foucault and Jacques Derrida, Brian Harley called on geographers and historians to deconstruct the Euro-American map, to uncover the power relations inherent to the positivist epistemology of Western cartography, and to explore the indigenous epistemologies silenced by the colonial cartographic tradition. Barbara Belyea, also through a close reading of Foucault, called for indigenous maps to be evaluated on their own terms rather than through comparison with a European “standard.” Robert Rundstrom further widened the theoretical critique by focusing on the transmission of knowledge itself. If nonindigenous culture is inscriptive, emphasizing the storage of information in objects for later use, and indigenous culture is incorporative, emphasizing the process of communicating knowledge itself, then maps as objects could no longer be a useful approach to the study of indigenous cartographies. A processual approach, Rundstrom wrote, would be a more culturally relevant and inclusive framework for Native map histories.

These theoretical contributions literally opened the eyes of Western geographers by redefining the nature of maps and mapmaking and bringing a wider awareness of indigenous map traditions. The landmark publication in 1998 of an indigenous volume for the History of Cartography Project solidified indigenous cartographies in map history, by compiling extensive research for the Americas and the Pacific, delineating the less well-known regions (including all of Africa), and articulating a new definition of the map to include more performative and word-based mapping traditions. Today, through an intersection of efforts from map history, anthropology, media studies, and indigenous social movements, the history of
indigenous cartographies from everywhere on Earth continue to be written into the global canon of indigenous map history.

Although mapping has been fundamental to indigenous self-determination and management of environmental and economic resources, as evidenced in the rise of participatory geographic information system (GIS), community GIS, tribal GIS, and online communities such as the Aboriginal Mapping Network and the Indigenous Mapping Network, these projects remain largely characterized by Western, nonindigenous map techniques and largely practiced by nonindigenous mapmakers. To this situation, the theoretical contributions of the field of indigenous cartography are relevant. In 1995, Rundstrom began to critique the positivist epistemological structure of GIS and the potentially harmful effect of such technology on traditional knowledge, drawing parallels to Native peoples’ marginalization by cartography during the colonial era. In 2005, the indigenous geographers Johnson, Louis, and Pramano called attention to the fact that as the inherent power and ubiquity of GIS is only likely to increase, it is imperative that indigenous communities are trained in the epistemologies embedded in their maps to avoid their remarginalization by cartography.

This dialogue about the epistemological underpinnings of geospatial technologies, and the impact of such technologies on indigenous cartographies and communities, is today an unresolved interdisciplinary discussion linking geography, international development, anthropology, and indigenous studies. New theoretical challenges include the incorporation of indigenous methodologies into mapping protocol and process, the spatial and visual encoding of the structures of Native science and Traditional Ecological Knowledge, and the interplay between indigenous and nonindigenous cartographies within each mapping project.

**Impact of Technology and Global Media**

Meanwhile, geospatial technologies are becoming more flexible in their sensory and design capabilities, indigenous peoples’ use of global media has become more intricate, and a multitude of innovative new mapping projects are being shared online. Many of these projects continue the traditional emphasis on storied place names as the heart of mapping indigenous cultural knowledge; as the representation of these names are evaluated and redesigned, the performative structures of traditional indigenous cartographies are gradually being incorporated. Audio and video technologies and the participatory benefits of blogging are now central to incorporating place-based stories into both tribal online GIS and indigenous cultural education sites, for instance, at the Web site Pepamuteiati Nitassinat (As we walk across our land), where Innu place names and stories are mapped with Google Maps, video clips, and elder recordings, and at the Bdote Memory Map, where Dakota people use blogs to tell stories and discuss the meanings of place names in the Twin Cities.

*Margaret Wickens Pearce*

See also Cartography; Cartography, History of; GIScience; Harley, Brian; Imperialism; Indigeneity; Indigenous Environmental Knowledge; Indigenous Environmental Practices

### Further Readings


Multiple terms have been used to describe the environmental knowledge and cultural resource practices of indigenous peoples, including indigenous environmental knowledge, traditional ecological knowledge, indigenous technical knowledge, and ethnoecology. The Western study of indigenous environmental knowledge is centuries old (e.g., Carl Linnaeus’s 1732 publication, *Iter Lapponicus*, included extensive descriptions of Sami indigenous environmental knowledge from Northern Scandinavia). There is a central paradox in the description and analysis of one knowledge and belief system from within the context of another, and the Western study of indigenous knowledge has been critiqued and challenged by numerous indigenous writers, in part because of the common assumption of the superiority of the Western tradition.

The United Nations Permanent Forum on Indigenous Issues states that there are around 370 million indigenous people in 70 countries across the globe. They have different social, cultural, economic, and political characteristics to those of the dominant societies in which they live. They are the descendants of those who inhabited a country or a region subsequently colonized by people of different cultures or ethnic origins. Territory and place are often central to indigenous identities, expressed through concepts such as land rights, sacred sites, and traditional resource use. These concepts are underpinned by unique indigenous environmental knowledge systems. While individually unique to particular people in specific geographic locations, there are nevertheless common aspects to these knowledge systems.

**Characteristics and Interpretation**

Some characteristics of indigenous environmental knowledge include a local or regional focus, oral transmission, a basis in practical engagement in everyday life, dynamism of form and content, integrated and holistic perspectives, and a situation within a broader cultural context. Although some of these characteristics are likely to be common to most systems of indigenous environmental knowledge, it is important to remember that terms such as *indigenous* and *Western* risk overgeneralizing what are diverse, complex, and dynamic groups. Similarly, separating indigenous environmental knowledge from its social and institutional context is inappropriate—it is unlikely to function merely as an adjunct to Western science, in isolation from the local social norms in which it was created. Many indigenous systems are based around cultural values such as respect and reciprocity, which are also a core element of the management processes that use the knowledge. Unsatisfactory outcomes are likely if these values are replaced by a simple resource utilitarianism.

While indigenous environmental knowledge is based on extensive empirical observation, its interpretation can be radically different from conventional scientific or Western paradigms. Fikret Berkes stresses that indigenous environmental knowledge centers on *relationships* between living beings, including humans. In contrast, heritage paradigms, among other common influential conventional scientific theories of value, have a focus on objects, entities, and places while the all but invisible background of relationships, behaviors, nonhuman entities, and kinship structures that arguably shape people-environment relations are ignored. Within indigenous environmental knowledge, there is often a strong correspondence between attitudes toward the environment and a belief in the sacredness of the living world, reflected in English translations of indigenous terms such as
caring for country, a community of beings, and all my relations. The Native American Tewa scholar Gregory Cajete uses the term *native science* to describe indigenous holistic and inclusive approaches to considering environments and their occupants and stresses the aliveness and connectedness of all things. “Native science” focuses on learning about an intricately interlinked universe rather than objectively explaining it. It also acknowledges mutual reciprocity: The world is not a resource for human use but a family of beings with mutual obligations and needs. This acknowledgment has compounded attempts at integrating indigenous peoples’ social and cultural values into natural resource management (e.g., in relation to water resource management in a thirsty agricultural continent such as Australia).

### Indigenous Environmental Knowledge and Resource Management

The increasing recognition of the value of indigenous environmental knowledge in natural resource management during the past few decades is embedded in a historical controversy surrounding the sustainability of indigenous environmental management. This controversy is arguably the result of a general lack of knowledge of, and lack of informed literature on, indigenous actors’ motivations behind environmental management practices in distinct socioeconomic and political contexts.

During the colonial era, indigenous environmental practices were often strange to the mindset of many Europeans. Limited European knowledge of the physical dynamics of tropical environments, for example, led to the dismissal of indigenous burning practices. Indigenous use of fire was instead labeled as an “evil” practice during the early 20th century, perceived to result in forest degradation and loss of colonial property. Such labeling of indigenous environmental management as unsustainable has increasingly been critiqued and refuted with the acknowledgment of nonequilibrium ecology. The recognition of savanna ecosystems as “unstable” has, for example, led to a gradual change toward acknowledging the value of fire in traditional indigenous shifting cultivation systems and bushfire protection schemes in savanna environments.

The indigenous use of fire in maintaining Northern Australian landscapes and ecosystems has been extensively investigated in collaborations between Western scientists and managers and indigenous experts. These attempts at collaboration provide recognition of the relationship between the importance of biodiversity in indigenous environmental knowledge systems and the acknowledgment that Western social and economic traditions have contributed to extensive global environmental degradation. Thus, in attempting to find solutions to the ongoing environmental decline, researchers have investigated worldviews that value the intrinsic rights of non-human others, suggesting that Westerners can learn from these belief systems.

However, environmental managers’ attempts in particular situations to incorporate effective indigenous practices into contemporary Western land management are often controversial and by no means broadly accepted, even in situations where indigenous people are numerically dominant. Indigenous environmental knowledge is also still often challenged today through a form of “ecological imperialism” that justifies an assumption of the superiority of Western knowledge over indigenous knowledge systems. In her notion of the colonization of discourses, Sandie Suchet proposes that Eurocentric discourses construct indigenous people and indigenous environments as resources to be developed or conserved by undermining or rendering indigenous environmental knowledge silent through a portrayal of indigenous people and their environments as pristine and unspoiled examples of nature.

While being alert to the dangers of essentializing and decontextualizing indigenous knowledge systems, it is also inappropriate to romanticize indigenous lifestyles and uncritically think of indigenous peoples as “ecological angels” or the “original conservationists.” There is a danger of seeing indigenous knowledge as something of an elixir for all the ills befalling communities in modern-day society. There usually is a range of environmental behaviors demonstrated in any group, which may include actions that have negative outcomes. Some reasons for this are that knowledge often is unevenly distributed among individuals, young people may have different views or knowledge, and
detailed local knowledge may be inadequate without knowledge on a broader scale, especially in changing environments. Some researchers have argued that conservation outcomes from indigenous environmental behavior are derived from a focus on optimal harvest efficiency rather than a desire to conserve species or habitats per se. Simply because it is deemed “indigenous knowledge” does not mean that it is necessarily more suitable than the knowledge of perceived “outsiders”; it must be fit for the purpose.

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Research on Indigenous Environmental Knowledge

Indigenous environmental knowledge has been investigated by several Western disciplines, including biology, geography, and anthropology. In biology, the congruence between indigenous knowledge and practice has been linked to concepts of adaptive management, and there is extensive work on the similarities between ethnotaxonomies and scientific ones. As examples, there are numerous studies of circumpolar peoples’ environmental knowledge systems that have repeatedly demonstrated the significance and efficacy of this knowledge. In Alaska, biologists conducting whale censuses had significantly more accurate results once they incorporated the knowledge of indigenous whalers. The 2004 Arctic Climate Impact Assessment, commissioned by the Arctic Council, used collaboration with indigenous peoples to access unique, long-term knowledge of weather patterns and flora and fauna distribution in compiling a compelling picture of rapid climate change in the Arctic.

In geography and anthropology, recent discussions about the extent and age of human influence on the environment have been linked with the voices of indigenous writers who are concerned with the place of nonhuman others in overall social and environmental relationships. This point, about the agency and intent of nonhuman actors, is probably most difficult for Western science to accept but has been repeatedly stressed by indigenous academics. The Maori biologist Mere Roberts argues against the removal of the spiritual dimension from scientific enquiry, emphasizing the presence of a moral universe. Indigenous writers have also challenged the

primacy of nonindigenous researchers in these discussions, arguing that it is not valid to interpret one belief system within the structures of another. Western concepts of objectivity undermine the distinctive position of indigenous knowledge systems that adhere to the rightness of their views. Increasingly, indigenous geographers themselves are exploring these issues, along with nonindigenous geographers working on indigenous geographies. These explorations, together with the increasing political voice of indigenous people, have shown that a distinction between indigenous environmental knowledge and perceived “outsider” knowledge does not by itself provide an adequate way to understand or overcome conflicts over land management and rights to land. Environmental knowledge is instead interwoven with, and divided across gaps in, daily resource politics at various scales—local, national, and international.

Christine Eriksen and Michael Adams

See also Environmental Ethics; Ethnicity and Nature; Ethnocentrism; Eurocentrism; Indigeneity; Indigenous Agriculture; Indigenous Cartographies; Indigenous Environmental Practices; Indigenous Reserves; Indigenous Water Management; Shifting Cultivation

Further Readings

INDIGENOUS ENVIRONMENTAL PRACTICES


INDIGENOUS ENVIRONMENTAL PRACTICES

Indigenous environmental practices can be thought of as a combination of behaviors, knowledge, and beliefs. In other words, indigenous practices are embedded in a larger sociocultural context that includes both the social institutions that regulate and convey knowledge and larger cosmologies. The concept of indigenous environmental practices is itself a nonindigenous construct, arising out of Western interest in those practices. There have been positive and negative consequences of outside recognition of these practices.

Indigenous environmental practices tend to be highly diverse and adapted to local conditions. Transmission can occur through storytelling, taboos, rituals, and underlying values such as respect, humility, and reciprocity. Elders and healers are often charged with the role of maintaining and conveying knowledge. Examples of such practices include the following:

- Monitoring of species numbers based on observed animal behaviors, life histories, movements and migrations, habitat and dietary preferences
- Controlling hunting or fishing of specific species, for instance, through animal totems and the recognition of taboo species
- Protection of specific habitats during various times of the year. Examples include the protection of headwaters because they function as fish spawning grounds or the protection of groves of trees planted by ancestors that function to attract various monkey species for hunting.
- Protection of species’ vulnerable life stages. This may include prohibition of the hunting of pregnant female or young animals.
- Various forms of resource rotation, both with regard to hunting and agricultural cycles. In agriculture, this can take the form of slash-and-burn (i.e., swidden) systems.
- Integrated farming practices such as polyculture. In polycultural approaches, two or more plant (and sometimes animal) species are planted in specific temporal or spatial orders to provide two or more outputs. The species planted together generally exist in mutually enhancing relation (ecologically or economically) to one another.
- The use of fire to shape landscapes. As has been documented in places as diverse as North and South America, Africa, and Australia, indigenous peoples have long used fire to control the movement, prevalence, and spread of wildlife and plant species, thereby creating intricate ecological mosaics, often invisible to outsiders.
- Knowledge and use of medicinal plants, including identification of the respective plants and the knowledge of how to process them. In many cases, indigenous peoples’ knowledge of medicinal plant has drawn the attention of outside scientists and bioprospectors, with little, if any, benefit to the indigenous communities. In the case of the neem tree (*Azadirachta indica*) in India or the Ayahuasca vine (*Banisteriopsis caapi*) in the Amazon, indigenous objections to the foreign use and patenting of native plants are both moral and practical. Such action has been termed *biopiracy* by indigenous leaders.

It should be acknowledged that the characterization of certain behaviors as “indigenous environmental practices” is a nonindigenous construct.
The label “environmental” implies a nature-culture dichotomy that is not necessarily shared in the same way by all indigenous peoples. The idea of “practices” implies the separation of knowledge from practice, when in fact the two often form a cohesive yet nonfixed and dynamic whole. Moreover, many “indigenous” environmental practices are complex hybrids of “modern” and “traditional” techniques.

For many years, colonial officials (and after them, scientists and developers) derided indigenous techniques as inert, unproductive, and archaic. Later research, however, revealed the intricacy of local practices, their high degree of dynamism, and the ability of indigenous practitioners to constantly reassess and adapt to changing circumstances. Whereas colonial authorities had blamed local practices for environmentally detrimental outcomes, scholarship in the later 20th century found that in many cases it was precisely the destruction of local knowledge and practices in favor of maladapted Western resource management methods that resulted in ecological deterioration.

More recently, outside interest in indigenous environmental practices intensified with the emergence of international environmental concepts such as “sustainable development” in the 1980s and 1990s. Against the background of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, indigenous peoples—especially those of the Amazon Basin—and their environmental practices emerged as potential “saviors” of industrialized society. There was recognition that most remaining biodiversity-rich regions of the world are also indigenous homelands. Such cartographical congruency lent credibility to indigenous claims that native peoples had protected and safeguarded the world’s fragile ecosystems. This approach led to a heavy phase of indigenous activism and numerous publications calling for the protection of both biodiversity and cultural diversity. The 1992 Convention on Biological Diversity emphasizes the desirability of protecting indigenous knowledge systems and practices for purposes of biodiversity conservation and sustainable development. In conservation policy circles, the interest in indigenous environmental practices expressed itself in the emergence of a new paradigm: community-based conservation.

In this framework, indigenous environmental knowledge and practices are recruited as ingredients of successful conservation.

As interest in indigenous environmental practices has increased, indigenous histories have experienced greater scrutiny (largely on the part of nonindigenous researchers). For example, while research emerged from the Amazon detailing that indigenous gardening techniques actually increased biodiversity in places, other scholarship in the same area highlighted perceived indigenous overhunting. While indigenous territorial rights were being put forth as a strategy to slow deforestation and biodiversity loss, practices deemed “environmental” became standards of “authenticity” that indigenous peoples now had to meet in order to have political currency.

Sonja K. Pieck

See also Community-Based Conservation; Indigeneity; Indigenous Agriculture; Indigenous Environmental Knowledge; Indigenous Forestry; Indigenous Reserves; Indigenous Water Management; Sustainable Development; United Nations Conference on Environment and Development

Further Readings


Indigenous forestry started getting recognition after the failure of state-dominated forestry, which excluded historical forestry management by indigenous and local communities. Indigenous forestry is defined as an approach that sees local indigenous forestry users as taking a central role in how their resources are managed and used. The indigenous forestry approach contrasts with conventional or scientific forestry, which brings in outside knowledge that indigenous people are then forced to use in planning, management, and use of their forests. Globally, there have been moves toward incorporating the interests of indigenous forest communities in Africa’s Congo Basin, the Amazon forest, and in southeast Asia.

The adoption of the Declaration on the Rights of Indigenous Peoples by the United Nations General Assembly in September 2007 has further highlighted the importance of 370 million indigenous peoples globally. Indigenous forestry relies on indigenous or local forestry use and practices that have been acquired over a long period of time. The recognition of the ownership rights of forests for the indigenous peoples goes beyond a moral necessity but is also socially, economically, and politically necessary.

Indigenous knowledge is important in indigenous forestry management. Most governments’ policies view indigenous communities as destroying forests. The expert view of foresters has largely continued with knowledge perceived as coming from the forestry experts to the indigenous communities.

There are many reasons for promoting indigenous forestry. First, indigenous forestry is often seen as a way of promoting sustainability. Since indigenous communities have managed and used forestry resources over many years, they have developed time-tested management systems that have ensured that forest resources would be available for future generations. Dependency on forests for various products such as food, medicines, and construction materials that are basic human requirements means that the indigenous communities will look after their resources.

Second, indigenous forestry is in line with the values of modern democratic society. Democracy values the input of local citizens who must have a say in issues that affect their lives. This is often referred to in terms of the subsidiarity principle. Justification for the subsidiarity principle blames centralized institutional arrangements by stating that local issues have to be addressed locally. Forestry is a local issue, where indigenous knowledge, if it exists in that locality, should be a basis for deciding on its management and use. This results in the crafting of locally specific and locally relevant rules. Indigenous forestry is one way of connecting the local views with higher levels of government.

Third, indigenous forestry is rooted in local culture, norms, and values. By allowing people to manage their forests using local norms and practices, we are more likely to make people follow their rules and regulations rather than if they were imposed by regional or central government. People’s beliefs should be central in any power relationship. Such power relationships can only be legitimate if they coincide with the beliefs, values, and expectations of a specific community. In the long run, it is argued that it is cheaper to enforce and monitor rules and regulations that are considered legitimate by local communities.

It is important, however, to avoid romanticizing everything that is labeled indigenous forestry. Those who oppose the use of indigenous forestry knowledge argue that science needs to lead development within the forestry sector. According to many analysts, most indigenous forestry decisions are based on morals that are not scientifically valid. While enforcement of forest management requirements is normally improved through local cooperation, this can also work against effective enforcement. Because of the close social ties among indigenous people, enforcing forestry rules and regulations against relatives might not be socially acceptable. This will result in forest management rules being potentially ignored under the indigenous management system.

Indigenous forestry is also blamed for perpetuating oppressive practices such as unfair treatment of women, which might be part of the broader indigenous customs and practices. Customary practices entrench gender, age, ethnicity, and class differences. This comes in sharp contrast with the goals, if not always the practice, of most modern democratic states. The customary norms and
practices might not be fair to the indigenous communities. Some tribal leaders or men might benefit more from the indigenous forestry practices, and this needs to be assessed critically. Mahmood Mamdani notes that governments, in pursuit of their own power, might selectively choose certain customs that bolster their own power—and not those of the indigenous communities.

The exclusionary forestry policy, based on science, is problematic since it does not take into account the indigenous knowledge systems and livelihood needs of the local people. Forestry policy has downplayed and even actively undermined the indigenous knowledge systems. The replacement of indigenous trees with monocultures of eucalyptus species in parts of India and the developing countries at large illustrates commercial interest in fast-growing species, which have revenue-generating potential, rather than ecological diversity. In the Amazon Forest and southeast Asia, for instance, huge areas of forests are being cleared for large-scale ranching and soy cultivation. Whereas global climate change is encouraging the maintenance of some indigenous forests as absorbers of carbon dioxide on the one hand, climate change has also resulted in the destruction of indigenous forests in a quest to grow biofuels to reduce fossil fuels consumption, such as the palm oil plantations in Malaysia and Indonesia.

Everisto Mapedza

**See also** Community Forestry; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Reserves; Indigenous Water Management

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**Further Readings**


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**INDIGENOUS RESERVES**

Many countries relocated indigenous peoples to make room for the settlement of newcomers. Canada and the United States created “reserves” and “reservations,” respectively, for this purpose. Because of their unique histories, and legal and political status, reserves and reservations differ from their surrounding territories. They are reminders of First Nations’ and Native Americans’ original ownership of the land in these two countries and the colonial processes that dispossessed them of their lands. Reserves and reservations continue to be culturally important communities for many First Nations and Native American peoples. This entry describes some characteristics and histories of reserves and reservations, pointing out similarities and differences between the two countries.

In Canada, Indian reserves are defined under the Indian Act (1976) as tracts of land set aside for the use of a First Nation band. The term *First Nations reserve* is more commonly used today. According to the U.S. Indian Reorganization Act of 1934, Indian reservations are lands managed by Native American tribes. In total, there are more than 600 occupied reserves in Canada, with an average size of 1,176 ha (hectares) (2,907 acres). Indian reservations in the United States tend to be larger. There are about 310 reservations in the United States, with an average size of about 180,000 acres. Nine U.S. reservations contain more than 1 million acres each.
While most reserves in Canada were created subsequent to treaty negotiations, some were created through other means, including grants to missionaries, purchases by First Nations, and federal and provincial legislation. Where reserves were created through treaty negotiations, First Nations chiefs attempted to create “homelands,” negotiating farming supplies and instructions. These reserves tend to be larger than reserves in Quebec, the Maritimes, and British Columbia, which were created primarily with the intent of facilitating assimilation. In Canada, most reserves were created through one legal strategy and are located on or near the First Nations’ traditional territory. In the United States, some reservations were created through treaty negotiations, which established reserves on tribal territories. Subsequent to the 1830 Indian Removal Act, many tribes were moved to reservations outside their traditional territories to clear land for settlement in the Eastern United States. Some reservations were purchased by a tribe or by the federal government, others were created through gifts, and some were created through executive orders or acts of Congress. Currently, most reservations contain lands obtained through different processes with resulting differences in legal status. Many reservations are located outside tribes’ traditional territories.

Subsequent to their establishment, the size of reserves and reservations in both countries was reduced. In Canada, this took place through expropriation, the surrender of land by First Nations communities (some illegally obtained),
and legislation. In the United States, the size of reserve lands was reduced by almost 60% by the 1887 General Allotment Act, which transferred tribal lands to individual private ownership, with subsequent sales. In the 1950s reserve lands were further reduced when the status of 61 tribes was terminated because they were regarded by the Bureau of Indian Affairs as no longer requiring federal assistance. The reduced size of reserves and reservations negatively affects possibilities for economic development.

In Canada and the United States, the title to reserve and reservation lands is held by the federal government. In both countries, they are exempt from taxation. In Canada, most reserves are administered by an elected chief and council type of government defined by the Indian Act (1876), with a level of jurisdiction close to those defined for municipalities, subject to the overriding supervision and control of federal or provincial governments. Some First Nations have negotiated additional powers through self-government agreements. However, Richard Bartlett has characterized the level of federal and provincial control over First Nations’ lands as subjugation. The 1934 U.S. Indian Reorganization Act offered tribes the possibility of forming elected tribal governments as well as tribal courts and police systems. Some tribes objected because these structures replaced traditional governments. On some reservations, two forms of government—traditional and new—continue to exist. In both countries, reserves and reservations represent political and administrative units that are unique from the territories that surround them. In both countries, First Nations’ and tribal governments’ jurisdiction does not extend outside the reserve boundaries, making it difficult to protect rights, for example, to water or to hunting and trapping.

Most reserves and reservations were created in rural and remote areas, far away from access to markets or services, with few natural resources. Because lands and the personal property of individuals, bands, and tribes located on the reserve or reservation are protected from seizure under legal processes, it has been difficult to obtain financing for economic development. The social conditions on many reserves and reservations reflect decades of government neglect. While there are exceptions, most reserves and reservations are characterized by low levels of economic development and high levels of poverty.

Nevertheless, many First Nations and Native American people value aspects of life in these communities. Resistance to assimilation created reserves and reservations as enclaves where cultures, traditions, and languages could be protected. For many First Nations and Native American people today, the meaning of these communities includes their significance as lands that they “reserved” for themselves in their relationships with newcomers. Despite the poor conditions on reserves and reservations, members of bands and tribes have some rights to housing, social assistance, and access to federal government programs. Recent federal government investments in health, education, and economic development have resulted in modest increases in employment opportunities on reserves. In both countries, tribes and First Nations have invested in gambling operations to increase revenues. Although the proportion of First Nations and Native American people living in cities has grown steadily since the 1950s, the size of reserve and reservation populations continues to grow. Despite earlier assumptions that reserves and reservations would disappear as their inhabitants assimilated or died out, these communities remain as unique elements of geographic landscapes in Canada and the United States.

Evelyn J. Peters

See also Colonialism; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Water Management

Further Readings

Indigenous Water Management

Indigenous water management refers to traditional approaches to accessing, collecting, treating, or distributing water that predate globalized industrial and capital- and energy-intensive methods that have spread primarily from Europe and North America. When referred to in the context of development, these methods are portrayed either as a historical accounting of natural resource management or at times as alternative, or techniques to be employed in support of, methods associated with modernity.

Due in part to their origination at a time when populations, markets, and infrastructure needs were radically different from what is commonly found in the modern era, indigenous water management methods are commonly scaled differently than those associated with modernity. While such methods may have supported a subsistence economy, they at times may not be scaled appropriately to suit what is by far the single greatest global use for water—regional commercial agriculture and trade. Indigenous methods can also be difficult to transfer to foreign settings, as they are rooted in specific geographic, social, and cultural contexts.

Culture

Indigenous knowledge derives much of its value from contextualized firsthand life experience, rather than from capital. Therefore, ritual is often intricately woven into indigenous water uses. For example, in Pohnpei, Federated States of Micronesia, the making of the “sakau” drink is a central part of an impassioned ritual that involves the grinding of a root that is a relative to the common pepper plant to produce a muddy-looking drink that has a relaxing effect. Interestingly, the clearing of forests in watersheds to grow the plant for distribution to Europe has created erosion and social problems that grassroots conservationists are now trying to tackle.

Access

In many areas, water has been treated as a “common pool resource,” or “commons,” and use has been typically guided by cultural beliefs and social norms. For example, in some rural areas outside Cluj, Romania, despite the increasing encroachment of the global market, neighbors do not run water pipes to homes, as it is assumed that water on someone else’s property is available for all to share at no cost.

Sharing water does not mean a lack of organization in its use. Globally, water sources have sometimes been segregated, with different sources reserved for certain levels of society for certain types of purposes (e.g., drinking vs. nondrinking). Water use was often governed or mediated by spiritual and ceremonial leaders in the community. The supernatural penalties expected to follow from violation of expected practices (inappropriate use of certain water, pollution of water, etc.) served to enforce local norms.

Depending on social structures, water can be more or less controlled by families, clans, tribes, and/or ruling elites. In such cases, payment can be required for access to water, especially for commercial purposes (e.g., for livestock), although water for basic household needs may be free. In mobile pastoral cultures, social and familial networks have been very important to negotiating access to water sources. Women are often the traditional collectors and primary users of water, so issues that shape indigenous water uses often affect them disproportionally (see the first photo).

Although what are perceived as indigenous or local methods are often contrasted with what are viewed as Western methods, the distinction is often not that clear-cut. Extant indigenous cultures are not isolated from the surrounding societies, Western and otherwise, and they often incorporate knowledge and technologies of practical benefit. For example, the second photograph shows how on the rural unelectrified island of Fefan, in Chuuk State, Federated States of Micronesia, modern polyvinyl chloride (PVC) pipes have taken the place of tree trunks to bring water by gravity from traditional dug-out springs lined with stone and a modern piece of tin. The hand-dug-out, near-surface groundwater lining with stone and gravity-fed approach is local, but the tin cover and PVC pipe are not.

Techniques for Collecting and Treating Water

There are interesting approaches to water quality management in different parts of the world. The clever complexity of these technologies generally
increases with pressures such as aridity or human population density. Some general methods of indigenous water management are presented below, but these should be considered as only a small sample of the methods actually used, and with many possible variations on each method discussed.

**Water Treatment**

Technologies for treatment include those used by some Indian women. The process consists of folding of sari material over a jug multiple times and tying it up with vines before dipping it into cholera-laden river water—this has been proven as an effective simple filtration method to mitigate cholera. Such ideas may sometimes hold more promise than expensive Northern high technologies and perhaps even create useful markets. This is an example of a technology that would be light to ship, simple to use in a decentralized manner, easy to clean by hanging in the sun, and simple to dispose of without hazardous waste. This type of “out-of-the-box” thinking, guided by best global South and island practices can perhaps be combined with Northern science for beneficial results—but only if applications are socially and geographically contextualized and partnerships are sustainable.

**Water Collection**

Perhaps the most high-profile dimension of indigenous water management has been the
modification of landscapes for the irrigation of croplands. Some major categories include the harvest or channeling of river water, rainwater, and floodwater and, to a lesser extent, of groundwater and springwater. Anil Agarwal and Sunita Narain have discussed the reestablishment of indigenous water management (which was ruined by the land use planning of the English during colonial times), in the form of small check dams to raise the water table.

**Bunds**

Cultures in many parts of the world have learned to farm on slopes by slowing overland flow with ground-level barriers that run cross-slope. These barriers may be of pegged vegetation or of stones, and they serve to slow water flow, increase soil absorption of water, reduce loss of soil, and increase capture of (fertilizing) runoff. When bunds are made of stone, they may evolve over time, as silt accumulates, to become terraces.

**Pits**

Pits collect and concentrate rainwater in small fertile plots. Sometimes indigenous areas of water collection are naturally occurring, such as that in the Valley of Fire near Las Vegas, Nevada, in the United States.

**Runoff Harvesting**

In many arid regions, cultures have relied extensively on agriculture fed by runoff from seasonal storms. Fields are made at the bases of hills or by leveling portions of drainages, such that runoff flows evenly over the fields when it rains. Where there are channels that experience more intense flooding events, canals could be cut into these channels to direct floodwater to fields.

**Watershed Delineation and Management**

Although many consider watershed management a Western notion, long before there were large watershed-based foundations or agencies performing watershed delineation, the ancient Hawaiian *ahu'ula* tradition flourished, with its delineation of watersheds that well matches present-day U.S. Geological Survey boundaries. Watershed-based management extended from "rim to reef," in acknowledgment of the social and ecological connectedness of land and fringing reef, and this spatial organization was essential to the daily use of land and water. Today, interest in this tradition is being rekindled in parts of the Hawaiian Islands. Indeed, indigenous water practices reflect much about the evolution of human-kind’s relationships with nature.

William James Smith Jr. and Nicholas Grenier

See also Common Property Resource Management; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Islands, Small; Water Management and Treatment; Watershed Management
Industrial districts refer essentially to spatial agglomerations of a specific industry and/or related industries. There is no commonly shared definition of an industrial district and, at times, it has been a source of debate among geographers and economists, but the concept entails concentrations of related firms, suppliers, other support industries, customers, and, of increasingly paramount importance, a high level of human capital.

These industrial regions are generally characterized by numerous small- to medium-sized enterprises (SMEs) rather than one or two large, vertically integrated companies. Within the industrial district, firms specialize in a wide range of functions encompassed by that particular industry. The atmosphere in such areas is notable for an environment that entails both cooperation and competition between companies. Cooperation includes the relationships between firms and suppliers, between suppliers at different levels, and between firms and customers, and even linkages between competing firms. Competition itself is supposed to be an advantage for an industrial district, as innovation is spurred through interfirm rivalries. Nowadays, many industrial districts are also marked by flexible production systems. Instead of the long production runs that were common to larger (and often Fordist) enterprises, the SMEs within an industrial district are typified by relatively smaller production batches and, most important, the ability to change production runs (by quality and type) quickly. This flexible production environment allows companies to respond swiftly to changing regional and global markets. Most often, lead times are minimized, stemming from reduced times across the research, design, production, and delivery stages. This dynamism is helped by myriad close relationships among different parties, both economic and social, fostered by spatial proximity. Much of the resulting knowledge in such regions is largely tacit—place or industry specific. This network of relationships and knowledge sharing enables the various actors in the industrial districts to react quickly to changing market demands and perhaps, more important, to innovate with regard to both products and processes.

At one time, and following the development of most advanced market economies, industrial districts were seen largely as concentrations of manufacturers and their related suppliers. Much has changed given the large movement of manufacturing activities to locations in emerging economies. The industrial districts of many advanced market economies, instead of production activities, now entail functions including research, development, design, marketing, and management. Given the structural changes in the global economy, moreover, an industrial district can also encompass agglomerations of service industries. Industrial districts can be found within cities or spanning entire regions of a country. By most accounts, the original idea of industrial districts stemmed from the concentrations of small firms in the textile, apparel, and shoe industries located in north-central Italy. Today, however, the term can be applied to locations as varied as Southern California’s entertainment industry, the city of London’s financial district, and, one of the most commonly referred-to examples, Silicon Valley.

Ronald V. Kalafsky
Industrial processes alter their surrounding environment through emission of waste products and through the use of natural resources as raw materials to create goods and services. Industrial ecology is the study of the interaction between these two systems (i.e., industrial and environmental), emphasizing the design of manufacturing processes that minimize waste and reduce environmental impacts. Uniquely viewing human industry as part of a dynamic, linked network that includes the environment and the economy, industrial ecology seeks approaches to sustainable use of resources that work well from a holistic perspective. Increasingly, industrial ecologists have broadened their questions and approaches to study and guide material use from “cradle to cradle,” as opposed to just “cradle to grave,” taking into account not just the relations among processes but also the broader infrastructures and social systems that constrain these processes and influence their development.

This young field of research has developed quickly from a foundation in the technical and physical sciences to an interdisciplinary intellectual community that includes academic journals and professional societies. Experts from a range of backgrounds, including the natural and physical sciences, public policy, and law, have joined a discourse that has expanded from questions regarding efficiency of material and energetic flows in industrial processes to include concerns about biodiversity, sustainable development, and public health. Specifically, research topics include determination of material inputs to production, improvements of environmental impacts through technological change, institutional and managerial responsibility for product design, development of eco-efficient industries and industrial parks, and policy incentives for environmentally friendly practices.

Further Readings


A Systems Perspective

A fundamental component of industrial ecology is the application of a systems perspective to technology and its surrounding environment. This holistic viewpoint of complex interactions maintains that a single part within a network can be best understood not in isolation but rather in the context of its relationship to other parts and its function within the larger whole.

An industrial system is a network of production and consumption built of several steps of varying complexity from raw materials to marketable products, to their use and return to the environment or other parts of the economy. This network exists within, and depends on, the larger ecosystem that provides a stock of natural capital for the creation of products and assimilation of wastes. The ways in which industrial processes are designed and end products are used determine the degree of environmental impact and, in turn, the condition of resources available for production. The socioeconomic environment also factors into decision making regarding the scale of resource use, the design of products and industrial structure, as well as the impact on the biophysical environment.

As with other complex networks, a perturbation in any part of the broad industrial-ecological system can cause rebound effects in other parts of the network. Because of this, implementation of solutions to problems must be done with care to avoid adverse rebound effects. For example, installation of green roofs and vegetation in cities can reduce air temperatures, leading to less energy use for air conditioning and water use for cooling in industrial buildings. However, because these solutions are water intensive, it is unclear whether the net water and energy savings would be positive in a given system. By favoring a comprehensive view over narrow partial analyses, industrial ecologists hope to avoid these rebound effects and exact changes that will have benefits throughout the whole system.
The Ecological Analogy

In its view of human industry as a dynamic component contained within the natural world, industrial ecology highlights the parallels between ecosystem processes and product life cycles. Similar to nutrients traveling through levels of a food web, production consists of a flow of energy and materials through a system (i.e., industrial metabolism), generating usable materials and high-entropy by-products. Because of constant reuse and recycling of waste products by organisms in nature, ecological systems are closed-loop cycles ultimately fueled by solar energy. Industrial ecologists apply knowledge of biological systems to mimic these cycles, with the goal of shifting industrial production from linear processes of unlimited waste to closed-loop cycles where nearly all waste is used as inputs for subsequent steps within the same company or as a resource for others.

Levels of Analysis: Tools and Applications

The view of industrial systems as integrated parts of the natural and social worlds requires analyses that span far beyond the technical and physical aspects of production. Tools used by industrial ecologists to limit the negative impacts of production on the environment thus range from highly specific investigations on particular segments of manufacturing chains to broadscale modeling, some of which include social and cultural considerations.

Evaluation of Existing Systems

Part of the challenge of transitioning from a linear, throughput-oriented production system to a closed-loop system is accounting for energy balances and resource flow from a product, from raw materials to the point at which it is no longer usable. These types of analyses have traditionally been thought of as “cradle to grave,” but industrial ecologists have become increasingly inclined to consider the “cradle-to-cradle” perspective, where a product at the end of its life cycle is reused for another purpose or recycled rather than discarded. Life cycle assessments (LCAs) are production budgeting tools used to inventory all transfers of energy and materials to the environment, to characterize the impacts of each release, and to identify areas for efficiency improvements to reduce impacts. One such area is the design of products for maximum reuse of its constituent parts. A systems perspective is particularly important in these analyses to ensure that potential improvements aren’t canceled out by the costs of rebound effects in another part of the network.

Because they tend to be oriented on single products or processes, LCAs are often interpreted in tandem with impact assessments of different foci. Environmental impact assessments, for example, evaluate and model waste emissions from entire plants or firms. Cost evaluation techniques (e.g., cost-benefit analysis) can then be used to compare potential methods to reduce impacts. Combining impact assessments from the perspectives of technical, ecological, and socioeconomic systems provides a comprehensive, higher-order picture of the industrial network for technical experts to use when considering efficiency improvements.

Change in Existing Systems

Technological innovation often plays a key role in moving from open- to closed-loop systems by increasing the efficiency of industrial processes or aiding in the recycling of waste products. The existing infrastructure of a given industry to a certain extent “locks in” production methods and efficiency, because upgrades and improvements to industrial capital can be very time-consuming and expensive. There is a burgeoning area of study within industrial ecology dedicated to the economics of such innovation, emphasizing the timing of change and improvements based on the technological inertia in the industry. Systems modeling is typically used to set potential schedules representing the most cost- and energy-efficient timescales for implementing innovative technological change. For example, the energy-intensive pulp and paper industry is a recent target for carbon dioxide emissions reductions. Researchers in Europe and the United States have used dynamic modeling to investigate the impacts of various policy options on emissions given the capital vintage structure (i.e., the lifetime capacity and age structure) of pulp and paper plants.
Industrial ecology emphasizes the design of new products that anticipates environmental impacts from the start, ideally saving manufacturers’ costs of cleanup or improvements in the future. The “design for environment,” or DFE, approach joins capital vintage approaches and comprehensive environmental assessments toward a forward-thinking view of design. Typically product oriented, this approach focuses on reduction of toxic material use, the potential for recycling, and manufacturer responsibility as a feature of product development rather than an afterthought. The movement toward green cars (e.g., hybrid and electric vehicles) from “end-of-pipe” mechanisms to reduce emissions (e.g., catalytic converters) represents an ongoing application of DFE.

Industrial Systems in a Social Context

Some industrial ecologists emphasize the social sciences as a critical part of the higher-level picture of industrial-ecological interactions and propose complex modeling approaches. Without an understanding of how to generate real changes in the human economy, some argue that many theories in industrial ecology will remain purely academic. To that end, behavioral studies of human consumption and waste patterns, for example, are employed to develop strategies for policies in the industrial world that will be successfully accepted and enacted.

Industrial Ecology in Practice

The archetypal example of industrial ecology in practice is an integrated production network in Kalundborg, Denmark. Borrowing the adaptive strategy of mutualism from nature, this and other eco-industrial parks share materials and energy among participating firms in an effort to achieve greater returns to production than can be achieved when each firm operates independently. These savings costs are incentives for firms to participate in business practices that often result in efficiency improvements and reduced waste emission. Six firms, including an oil refinery, a plasterboard firm, and a pharmaceutical company trade waste for reuse and recycling, recover solvents for manufacturing processes, and share transportation and security services. Over the past 30 years since the park was founded, evolution of the symbiosis has amounted to substantial annual energy savings; for example, resource exchange between the refinery Statoil and the power station Asnes saves the firms 1.2 million cubic meters of water and 30,000 tons of fossil fuel per year, respectively.

Businesses from around the world are beginning to apply industrial ecological approaches from the eco-industrial park model to smaller-scale partnerships. Texas Industries, for example, enjoyed an increase in cement production and decrease in energy consumption following a 1999 agreement to reuse waste products from neighboring Chaparral Steel. Similar symbiotic developments have emerged throughout the United States and in Japan, Canada, and Puerto Rico, among other places.

The Future of Industrial Ecology

Partly because of its relative youth as a field of research and practice, industrial ecology faces challenges in terms of its scope and direction. Although there has been a distinctive move to include social and cultural questions as previously described, there still is some disagreement about how large a role these concepts should play in the field. There is an active theoretical body of literature focused on moving industrial ecology forward by synthesizing and refining its goals, aims, and breadth.

As the epistemological facet of industrial ecology continues to evolve, there has been difficulty in translating the resulting theories and ideas into application on a larger scale. Although small-scale efficiency improvements can be relatively easy to understand and implement, wider-reaching projects such as the eco-industrial parks have proven more difficult to develop. The current focus on creating sustainable networks of industry will likely remain an active area of research and application in the future as more businesses become interested in how partnerships for the environment can also be potentially profitable.

Similarly, the policy perspective will play a critical role in determining the extent to which novel and innovative ideas are manifested in the industrial world. Use of the market to provide incentives to businesses to implement the ideas and
technologies that are derived from the aforementioned tools and analyses is a critical part of recent discourse. There is an ongoing effort to examine the institutional and organizational barriers to the greening of industry in order to identify practical mechanisms (e.g., ecological tax reform) to create a favorable environment for sustainable development. Similar efforts are encouraging firms to see industrial ecological concepts as opportunities rather than burdens.

Rebecca R. Gasper and Matthias Ruth

See also Agent-Based Models; Complex Systems Models; Energy Models; Environmental Impacts of Manufacturing; Sustainable Production

Further Readings


Industrialization refers to the economic growth and processes occurring at any geographical scale, ranging from a metropolitan region to an entire country. Historically, these processes entail the initiation and development of a manufacturing sector that first specializes in basic activities that include the production of commodity-type goods. Before this initial industrialization stage, many regions or countries are heavily involved in the primary economic sector, in agriculture and/or extractive activities. In the case of some countries with few or no natural resource endowments, reliance on the primary sector is untenable, thereby compelling countries into rapid industrialization.

The initial stages of industrialization (basic manufacturing) take advantage of the low-cost advantages that a newly industrialized region or country has, centered on available labor, natural resources, and/or a large market. Next, as levels of human capital and overall capital accumulation rise, production activities move toward advanced manufacturing activities, entailing increased technical sophistication and decreased economic reliance on manufactured goods. The end result is that the overall economic wealth increases and industrial activities become diverse and increasingly complex. This transition also includes the establishment of advanced manufacturing functions such as research, design, logistics, and management as production moves to offshore sites. This transition has been a cause for concern in many advanced market economies, given their large losses of production-related employment. Recent economic history has also suggested that the industrialization process also encompasses a move toward a varied and sophisticated service sector.

Industrialization, as it is generally understood, took place during the Industrial Revolutions of Great Britain, Western Europe, and the United States during the mid 19th century. Japan rapidly developed during the late 19th and early 20th centuries. Notably, Japan again achieved rapid industrialization in the decades following World War II, developing into the world’s second largest economy. Similar swift industrialization paths occurred in South Korea and Taiwan, to provide just two examples. Currently, industrialization processes are occurring, at different rates and at various stages, across the world. The most visible examples are found in the recent, rapid economic growth witnessed in China and India.

A noteworthy point is that economic history has demonstrated that no single, clear-cut path to industrialization exists with regard to the methods, types of industries, or even the institutions involved in the process. Geographers and other researchers have been interested in the conditions
and forces that most often make each industrialization process unique with regard to its pace, methods, institutional involvement, and end results. The paths to industrialization in the United States and Britain were considered to have been largely led by the private sector, but even these economic transitions often involved degrees of policy-led participation. In Western Europe, industrialization entailed a large degree of public sector/private sector interaction, but again, this varied by country. In the above examples, industrialization often started with industries such as textiles, then progressed with heavy industries such as steel and chemical production. A goal was to serve domestic markets and, secondarily, to export to other markets, which sometimes included colonies. For Japan and throughout much of East Asia (with many countries basing growth policies on the Japanese model), the links between government and industry were close. In these instances, government played a strong advisory role, formulating a strong industrial policy. Trade policies such as import substitution and export promotion were also implemented with the aim of achieving rapid economic growth, stability, and higher standards of living. The point to be made with regard to industrialization is that even opinions about government involvement or market structure (e.g., regulation of monopolies) have been viewed quite differently. All the above situations involved industrialization with the end goal of economic development. However, the means to achieve these goals and the paths that were taken have been quite different.

An overwhelming feature of industrialization is its spatial unevenness. This apparent unevenness occurs at a variety of scales, within regions, within countries, and, as has been noted by numerous observers, on a global scale. In many cases, differences in the rates of industrialization have led to core-periphery unevenness in development. Consequently, geographers are interested in the spatial effects of industrialization, including the impacts on labor, firms, markets, governments, and the environment.

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See also Flexible Production; Industrial Districts; Industrial Revolution; Manufacturing Belt

Further Readings


Industrial Revolution

Although capitalism has been a dynamic socioeconomic system since its inception, the pace of technological and social change accelerated exponentially in the 18th and 19th centuries with the Industrial Revolution. It is important not to equate capitalism and industrialization, for they are not synonymous. Historically, the Industrial Revolution occurred long after capitalism began; indeed, for most of capitalism’s history, it involved preindustrial forms of production, including artisanal and household types. However, starting in the mid 1800s, an explosive increase in the speed and productivity of capitalist production occurred that transformed the worlds of work, everyday life, and the global economy. Industrialization is a complex process that involves multiple transformations in inputs, outputs, and technologies.

Three dimensions are particularly important here: (1) the use of inanimate energy, (2) technological innovation, and (3) increased productivity. This entry first describes these aspects of the Industrial Revolution and then examines its geographical development, cyclical nature, and global impact.

Inanimate Energy

If preindustrial societies relied and continue to rely on animate sources of energy (i.e., human and animal muscle power), industrialization can be defined loosely as the harnessing of inanimate sources of energy. The first of this type was running water in waterwheels, a source used since the late feudal era to grind corn and flour and to saw wood. Running water was a major source of energy in the earliest stages of the Industrial Revolution, but it constrained firms to locating near streams and rivers; moreover, most streams are ephemeral, that is, they do not flow all year long.

A more efficient source of inanimate energy involves the steam engine, originally designed by
Thomas Newcomen in 1712; the first prototype, however, was built by the Scottish engineer James Watt in 1769 as part of an effort to expunge seawater from coal mines that reached under the ocean. The steam engine marked a decisive turning point in the process of industrialization, with widespread applications in several areas of production and transportation. Wood provided the first major source of fuel for this invention, which required heating water into steam to drive the engine’s pistons. As producers began to cut down forests in Britain in large numbers, deforesting much of the country, wood supplies began to dwindle, and the rising cost eroded profits. As wood became scarce, producers switched to coal. Thus, as Britain industrialized, several areas became major coal-producing centers, including Southern Wales and Newcastle. As the Industrial Revolution spread across the face of Europe in the 19th century, the large coal deposits of the Northern European lowlands became increasingly important, fueling the growth of manufacturing complexes in Belgium, Northern France, Northern Italy, Germany, Poland, and the Ukraine. In the United States as well, Appalachian coal played a key role in the nation’s industrialization, and that industry flourished hand in hand with the rise of the Manufacturing Belt. In the late 19th and 20th centuries, coal was joined by other fossil fuels, particularly petroleum and natural gas. The abundance of cheap energy was the lifeblood of industrialization, and production became increasingly energy intensive as a result.

**Technological Innovation**

The Industrial Revolution witnessed an explosive jump in the number, diversity, and applications of new technologies. A technology can be defined simply as a means of converting inputs to outputs. These can range from extremely simple to very sophisticated. As industrialization produced an increasingly complex division of labor, as noted by Adam Smith, opportunities for new inventions rose rapidly. These innovations were employed in agriculture, in manufacturing, in transportation and communications, and in services.

In the Industrial Revolution, a major reorganization in the nature of work occurred with the development of the factory system and a far more detailed division of labor both within and among firms. Prior to this era, industrial work was organized on a small-scale artisanal basis, including home-based work. By the late 18th century, firms in different industries were grouping large numbers of workers together under one roof, a process that effectively created the industrial working class. Inside factories, workers used vast amounts of capital, that is, many types of machines. The introduction of interchangeable parts, invented by the American gun maker Eli Whitney, made the production and operation of machines much cheaper and more reliable. By the early 20th century, Henry Ford introduced the moving assembly line, which further accelerated the tempo of work and the ability of workers to produce.

**Productivity Increases**

As a consequence of the technological changes of the Industrial Revolution, productivity levels surged. Productivity refers to the level of output generated by a given volume of inputs; productivity increases refer to higher levels of efficiency—that is, greater levels of output per unit of input (e.g., labor hour or unit of land) or, conversely, fewer inputs per unit of output. Productivity levels rose exponentially in the 19th century throughout the industrializing world. As the cost of producing goods declined, standards of living rose correspondingly. Most workers labored long hours under notoriously exploitative conditions and endured a standard of living quite low compared with those we enjoy today. But nonetheless, over several decades, industrialization saw many kinds of goods become increasingly affordable to the growing middle class. Because wage rates have been linked historically to the marginal productivity of labor, the working class became significantly better off. Most important in this regard concerns the industrialization of agriculture. As food became progressively cheaper, diets improved as more people ate more and better food than ever before, with corresponding improvements in infant mortality rates and life expectancy. With the notorious exception of the Irish Potato Famine of the 1840s, hunger and malnutrition gradually declined throughout Europe.
The Geography of the Industrial Revolution

The Industrial Revolution unfolded very unevenly over time and space. Whereas capitalism had its origins in Northern Italy, industrialization was very much a product of northwestern Europe. Some observers put the first textile factories in Belgium, in cities such as Liège and Flanders, with a tradition that dated to late medieval times. However, it was Britain that became the world’s first industrialized nation, a status that likely reflected, among other things, its extensive network of trading ties and prior commercialization of agricultural land through the Enclosures. By the end of the 18th century, Britain stood virtually alone as the world’s only industrial economy, a fact that gave it an enormous advantage over its rivals and propelled it to the status of world hegemon. Cities in the Midlands of Britain, such as Leeds and Manchester, were known as the “workhouses of the world” for their high concentrations of workers, capital, and output. Others, such as London, Glasgow, and Liverpool, became shipbuilding centers. In many cities, networks of producers in guns, watches, and light industry formed dense industrial districts.

A half-century after it began in Britain, the Industrial Revolution diffused to the European Continent, North America, and Japan. In France, this process saw the formation of industrial complexes in the lower Seine River, Lille, and Paris. In Italy, Milan and the Po River valley became a major producer of textiles and shoes. In Northern Spain, Barcelona became an important center. In Scandinavia, cities such as Stockholm became major ship producers. In Germany, which was late to industrialize, the Ruhr region became a global center of steel, automobile, and petrochemical firms in the late 19th century, propelling that newly unified nation to global prominence.

By the early 19th century, the revolution leapfrogged across the Atlantic, igniting the industrialization of Southern New England with the growth of the textile industry there. In New York City, a huge complex of light manufacturing arose, centered on garments but including many other small firms. Philadelphia became a large center of ship construction. Stretching across the southern shores of the Great Lakes, the Manufacturing Belt became the second largest industrial region in the late 19th century, following Britain, largely on the basis of the steel, rubber, tool and die, agricultural implements, and automobile industries. However, industrialization also dramatically affected agriculture and meat packing.

Russia did not become industrialized until the 1920s and 1930s, when the Soviet Union under Stalin leaped to become the world’s second largest economy in the span of a decade. Under the Soviet system, heavy manufacturing, particularly steel and armaments, was emphasized over sectors producing consumer goods. Starting in the 1870s, Japan became the first non-Western country to join the industrialized nations, developing a formidable industrial base in steel, railroads, armaments, textiles, and ship building that fueled its expansionary growth and militarism.

In the late 20th century, the process of industrialization diffused to many developing countries, particularly the East Asian Newly Industrialized Countries (NICs) such as South Korea, Hong Kong, Taiwan, and Singapore, many of which borrowed liberally from the Japanese model. More recently, Thailand, Indonesia, and Malaysia have moved down this path. Rapid economic growth in China today represents another stage in the industrialization of Asia, including the production of textiles, toys, and electronics. Similar events occurred in Mexico and Brazil, including the maquiladores in the former and an electronics and aerospace industry in the latter. In a sense, the industrialization of the developing world, which is still very partial and incomplete, is a continuation of a long-standing historical process.

Cycles of Industrialization

The nature and form of industrialization varied in successive historical periods. Capitalism is prone to long-term cyclical shifts in its composition, often in waves of roughly 50 to 75 yrs.’ duration, often known as Kondratief waves. This process saw the rise of different industries at different times. Industrialization was thus not one process but a series of them that varied over time and space.

The first wave of the Industrial Revolution (1770s–1820s) centered on the textile industry. In Britain, as in the rest of Europe, North America, Japan, and the developing world today, textiles
have *always* led industrialization. Easy to set up, with few requirements of capital or labor skills, this sector initiated the industrial landscapes of most of the world. Because this early wave of industrialization was centered in Britain, it witnessed that nation become the leading economic power in the world, initiating the period of the Pax Britannica.

The second wave, from the 1820s to the 1880s, was a period dominated by heavy industry. In the 19th century, sectors such as shipbuilding, railroads, and iron and steel plants were critical. Large scale and capital intensive, these types of firms differed markedly from the light industry of textiles. They required massive capital investments, an infrastructure often built by the state, were difficult to enter, and moved toward an oligopoly rather than a competitive market structure. This was the period in which the U.S. Manufacturing Belt began to form, although most of its growth was after the Civil War of the 1860s.

The third wave of industrialization, from the 1880s to the 1930s, saw numerous heavy industries appear, including steel, rubber, glass, and automobiles. This was a period of massive technological change, including capital intensification and automation of work, as well as economic changes. As local markets gave way to national markets, most sectors experienced a steady oligopolization, or concentration of output and ownership in the hands of a few large firms led by robber barons.

In the fourth wave of industrialization, which started during or immediately after the Depression of the 1930s and lasted until the oil shocks of the 1970s, the primary growth sectors were petrochemicals and automobiles. It is often associated with Fordist systems of mass production. With a relatively stable global economy, this era saw the domination of the world system by the United States, which produced a huge share of the planet’s industrial output, including, in the 1950s, two thirds of its steel and 60% of its automobiles.

The fifth wave of industrialization, often held to begin after the oil shocks of the 1970s that ended the post-World War II boom, has been led by the electronics industry, which was powered by the microelectronics revolution and by the explosive growth of producer services.

During each era, the major propulsive industry was commonly featured as the “high-tech” sector of its day. Thus, just as electronics is often celebrated at this historical moment for its innovativeness and ability to sustain national competitiveness, so too were the textile industry in the 18th century and the steel industry in the 19th century associated with high levels of productivity and wages.

**Consequences of the Industrial Revolution**

The Industrial Revolution permanently changed the social and spatial fabric of the world, particularly in the societies that now comprise the economically developed countries. Within a century of its inception, industrialization transformed a series of rural, poverty-stricken societies into relatively prosperous, urbanized ones. It is no exaggeration to credit industrialization with the rise of modernity in all its complex forms.

The Industrial Revolution essentially created the modern working class. For the first time in human history, large numbers of workers labored together using machines. These conditions were markedly different from those facing agricultural or artisanal workers, who were dispersed over large spaces and relied on animate sources of energy. Industrialization gave rise to organized labor markets in which workers were paid by the hour, day, or week. This process was not easy, given how brutally exploitative working conditions were during this time. Workers typically labored for 10, 12, even 14 hours per day, 6 days per week for relatively low wages. Often the work was unsanitary and dangerous, even lethal, as workers were subjected to abusive employers, accidents, poor lighting, and poor air quality. Child labor was also common, subjecting those as young as 4 or 5 yrs. of age to horrendous conditions.

As the result of this process, time—like space and so much else—became a commodity, something bought and sold. The transition from agricultural time to industrial time was important. Prior to the Industrial Revolution, people experienced time seasonally, with different tasks at different times of the year, and rarely felt the need to be conscious of it, for precision was unnecessary. With industrialization, however, time was measured and divided into discrete units, as signaled
by the factory whistle, clock, bell, and stopwatch. This change marked the commodification of time through the labor market.

Industrialization also produced labor unions. The first resistance to employers included the British Luddites in the late 18th and early 19th centuries, who blamed their miserable working conditions on the machines they used and often destroyed them in attempts to halt their exploitation. By the late 19th century, organized labor had created a number of unions, which in the United States included the Knights of Labor, the American Federation of Labor (AFL), and in the 20th century, the Industrial Workers of the World and the Congress of Industrial Organizations (CIO, which later merged with the AFL to form the AFL-CIO). Industrialization was thus often a period of considerable class conflict.

Geographically, the Industrial Revolution was closely associated with the growth of cities. Almost everywhere, industrialization and urbanization have been virtually simultaneous processes. The reasons why firms concentrated in cities are important. Cities were clearly centers of capital as much as they were centers of labor. There are powerful reasons for firms to concentrate, or agglomerate, in cities. Most firms benefit by having close proximity to other firms, including lower transport costs to suppliers of parts and ancillary services, and access to an infrastructure, specialized information, and the labor force. As complexes of firms sprouted in cities, industrialization changed the character of societies from predominantly rural to predominantly urban. In Western Europe, North America, and Japan, for the first time in history, the majority of people

Spinners at Cherryville Mfg. Co., North Carolina, 1908. During the Industrial Revolution, child labor was common, subjecting those as young as 4 or 5 yrs. of age to horrendous conditions.

lived in cities. In the United States, for example, the first national census of 1790 showed that 95% of Americans lived in rural areas. This proportion decreased throughout the 19th century, and by 1920, 50% of the nation’s population lived in cities. Today, it is roughly 85%, a proportion that is found in most economically developed countries.

Industrialization also shaped the population growth rates and demographic composition. On the eve of the Industrial Revolution, the famous theorist Thomas Malthus predicted that rapid population growth would create widespread famine. Yet Malthus was soon proven to be wrong, at least in the short run. The industrialization of agriculture generated productivity increases greater than the rate of population growth, and the creation of a stable food supply improved most people’s diets. As a result, life expectancy rose. Industrialization also lowered death rates, particularly as malnutrition declined and infant mortality rates dropped. Eventually, public health measures and cleaner water helped control the spread of most infectious diseases. As death rates dropped, the populations of industrializing countries increased dramatically. This change was also accompanied by a shift from the extended to the nuclear family. Eventually, industrialization also led to a decline in the birth rate; families had fewer children, and population growth rates declined.

Yet another impact of the Industrial Revolution concerned the global economy. Capitalism had formed a loose network of international trade well before the 18th century. The harnessing of inanimate energy for transportation dramatically accelerated the speed of both land and water transportation, notably through the railroad and steamship, forming a significant round of time-space compression. New, industrialized forms of transportation were not only faster but also cheaper, resulting in cost-space convergence or compression as well. These changes dramatically lowered the barriers to trade, and the volume of imports and exports began to soar. Europe, starting with Britain, could import unprocessed raw materials, including cotton, timber, sugar, wheat, and mineral ores, and export high-value-added finished goods, a process that generated large numbers of jobs in Europe and contributed to a steady rise in the standard of living.

Finally, the industrial world economy saw an explosion of international finance. British banks, largely concentrated in London, for example, began to extend their activities on an international basis, lending to clients and investing in markets overseas. Much of the capital that financed the American railroad network was from Britain. The globalization of production was thus accompanied by the steady globalization of money and credit.

Barney Warf

See also Agglomeration Economies; Agriculture, Industrialized; Automobile Industry; Business Cycles and Geography; Demographic Transition; Economic Geography; Fordism; Industrialization; Malthusianism; Manufacturing Belt; Textile Industry; Time-Space Compression; Urbanization

Further Readings


INEQUALITY AND GEOGRAPHY

Human geographers became directly interested in the study of inequality when the focus of the discipline shifted to examining spatial differences using quantitative methods and exploring how different variables varied across space. Typically, such variations occurred across a country or city, although a few scholars were interested in variations across
the globe. At first, the main focus was on how to map, measure, and explain variations, but gradually more normative approaches began to address welfare and justice issues. How did the differences among areas that were being observed affect human life, and insofar as they did, how could the negative aspects be remedied? When Marxism began to influence the discipline in the 1970s, interest in spatial variations was transformed into a stronger, more explicit concern for inequality in all its dimensions. The world was unfair, and something needed to be done to remedy injustices. Of course, for many Marxists the only answer was the demise of the capitalist system.

In recent years, many human geographers have continued to be interested in the broad inequalities in and across societies, but arguably most have concentrated on the problems of specific groups. The unfair treatment of women, black people, ethnic minorities, gays, migrants, those with HIV/AIDS, and others has dominated geographical journals. Only development geographers have really been interested in poverty on a global scale, and only those writing in the more left-wing journals of the discipline, such as *Antipode*, have focused on class. With the shift to postmodernism and poststructuralism, geographers have tended to neglect the normative and policy issues linked to inequality and have focused on how unfairness has developed over time. Postmodern thinkers are typically more interested in discourse analysis and differing interpretations of reality than in remedying past and present wrongs. The idea that progress is possible has diminished in importance by questioning what progress means and whether it is actually desirable. Inequality is integral to postmodern and postcolonial discussions but mainly takes the form of showing how one group or another has been harmed as “progress” or “development” has occurred.

Of course, the field of geography has always attracted a substantial number of those who wanted to get involved in policy issues, but it seems that most geographers are currently less interested in influencing policy than they once were. Those who do get involved in policy work tend to be dismissed as empiricists, insufficiently engaged with theory to take their place at the forefront of the discipline.

### Why Is Inequality Important?

That question, of course, is highly political. However, most observers would agree that inequality is undesirable if it means that the wealth of some people and places causes the poverty of others. Such a situation is certainly true in the rural areas of Latin America, where limited numbers of families control most of the cultivable land, a situation that was also once also common in Europe. Dependency theorists argue that the wealth of the developed countries has been accumulated at the expense of the “Third World” and that without a redistribution of wealth and resources, billions of people will continue to live in absolute poverty.

Inequality is also important for political reasons. Much of the conflict that has occurred across the globe has been caused by ill feeling over the distribution of resources. This resentment has sometimes taken the disguised form of racial or religious intolerance, but the underlying cause has typically been that one group is much better off than another. Such might be the explanation of the Protestant/Catholic struggles in Northern Ireland, the Palestine/Israel problem, and the genocide that occurred in Bosnia and Croatia, in Rwanda and, currently, in Sudan. It is also a likely cause of the riots that have occurred in some cities in developed countries, such as those in the Watts area of Los Angeles in the 1960s, the interracial hostility in some northern cities of the United Kingdom early in the new millennium, and the French riots of 2005. If class-based revolution is less likely than Marxists once believed, inequality is at the heart of much of the violence, actual and potential, going on in the world today.

Most people would accept that some degree of inequality is inevitable and some even that it is desirable, but how much inequality is acceptable? This question is actually unanswerable because everyone’s view on the matter will be different. Some scholars, particularly economists, argue that inequality is necessary to create the incentives and capital necessary to generate the wealth that will remove poverty, although that view begs the question of how large those incentives need to be. Chief executive officers (CEOs) today earn much larger salaries than they did two or three decades ago. Would they not want to lead their corporations if
their annual pay was in the hundreds of thousands of dollars rather than in the millions? On the other side of the political divide, some still agree with Karl Marx’s aphorism, “From each according to his ability, to each according to his needs,” even if experience over the years has suggested that this principle has not worked very well in practice. Most people adopt an intermediate position, but what precisely is that?

The only way any such position can be established is through political debate and struggle. If the poor person or the black or the Muslim begins to protest, the question of inequality rises to the fore of the political agenda. If people begin to starve, even though they do not have the strength to protest, then most people would accept that there should be a transfer of resources. Of course, protest is more effective when it occurs on the doorstep of decision makers. Injustice is easier to ignore in Africa than it is in the inner city ghettos of developed countries. For policymakers, and for much of the public, the genocide and starvation occurring in Darfur are a long way away, and thus invisible.

How Do We Measure Inequality?

Equality is relatively easy to measure empirically. In an equally developed society, everyone would earn the same income, every birth would be attended by a health care professional, and every child would start school at the same age and receive the same quality of education. Achieving total equality is, of course, impossible, but we can conceptualize what it means and measure it fairly accurately.

Inequality, by contrast, is more complicated. First, all kinds of measures of inequality are available, and they all produce different results. Measures such as the Gini coefficient, Theil’s $T$ statistic, the index of dissimilarity, and so on all provide different answers because different statistical assumptions underpin their calculation. Second, trends in inequality also vary according to the time period and the scale over which inequality is measured. If statistics do not lie, they can certainly be manipulated to produce the answers that the analyst wants to find—something particularly likely in the study of inequality.

What Are the Main Features of Inequality?

Differences According to Scale

World Scale

No one can doubt that inequalities among nations are extreme. Today, the total income of the richest 25 million Americans is equal to the total income accruing to almost 2 billion people, 30% of the world’s population. Of course, the degree of difference clearly varies according to the indicator we use and how we divide the world, but living conditions for the majority of those living in sub-Saharan Africa and the Indian subcontinent are clearly appalling when compared with the affluence of the majority in developed countries.

Whether those differences are increasing or diminishing is open to debate. One claim is that the ratio of average incomes in the industrialized and developing countries rose from roughly 30:1 at the end of World War II, to 60:1 in the 1970s, to more than 90:1 by the early 2000s. However, other figures show something different; indeed, according to which numbers are used and over which period of time, the data show several different trends.

Equally, there are doubts about the relationship between poverty and inequality. Some scholars argue that poverty has declined in the world over the past decade or so, mainly because living conditions for many East Asians, particularly Chinese people, have improved markedly; others question the level of the poverty line and suggest that it has not. Certainly, while the relative numbers living in abject poverty have declined in recent years, the absolute decline in the numbers of poor people is much less impressive.

National Scale

Since 1980, the distribution of income in virtually every country in the world has become more unequal, particularly given the hegemony of neoliberalism. The rich have seen their share of total earnings and wealth increase rapidly, whether it is in the United States, China, or Brazil. There are many drivers of this inequality, including globalization, regressive taxation, and the growth of unearned income (e.g., dividends). Today, the
world’s ultra-rich are not confined to the United States and Western Europe; a few very rich people have emerged in China, India, Mexico, and most oil-rich countries of the Middle East. Equally, large numbers of poor people have moved in search of work into countries with higher incomes, increasing their national levels of inequality.

**Regional Scale**

Unlike national inequality, regional disparities within countries have sometimes diminished. In Mexico, the past 30 years have seen the north of the country prosper relative to some of the older established industrial centers, although the south continues to struggle. In some places, regional differences have declined because new resources have been exploited, raising the incomes of some poorer regions. Occasionally, government action has managed to reduce inequalities. Sometimes the poor have moved out of poor areas to more prosperous places, even out of the country altogether. But arguably, differences among regions are insignificant because they are effectively determined by more fundamental causes such as income variations by social class and ethnicity. Most poor regions have a much higher proportion of working-class people or ethnic minorities. And when regional incomes rise in a poor area, often it is only the local elite that benefits.

**Local Scale**

Most urban areas appear to be becoming more unequal. Certainly, global cities are becoming more polarized as the salaries of the highly skilled are determined by global markets while their needs are serviced by a relatively impoverished, often immigrant, “underclass.” Fearing crime and violence, the more affluent protect themselves by living in “gated communities” or in apartment buildings heavily protected by security cameras and guards. Whether this tendency is as marked in nonglobalized cities is unclear, but where social inequality is rising, it is likely that residential segregation will follow.

**Differences by Social Group**

Arguably it is social and political processes that explain most geographical variations.

**Gender**

On average, throughout the world, men earn more than women, although the difference between the sexes is being reduced in most developed countries. In many poorer countries, however, the divide is still marked. If today Indian widows rarely throw themselves on their dead husbands’ funeral pyres, their daughters still live shorter and more brutish lives than their sons. Generally, discrimination between the sexes is more marked at the bottom of the social ladder than at the top. This trend is reflected in the number of female politicians and legislators who have gradually gained power in recent years. However, the conditions in which poor women in Africa, Asia, and Latin America live tend to be distinctly less positive than those of poor men. Women work harder than men, earn less money and respect, and have fewer opportunities for education or higher-paying jobs.

**Ethnic and Racial Differences**

In most countries, ethnic groups do less well than the majority. White-skinned people in Latin America tend to be more affluent than darker-skinned people, and relatively few live in favelas or squatter settlements. In the United States, African Americans and Hispanics/Latinos are generally much poorer than whites, have less education, are less likely to own homes, and are more likely to be unemployed. Legislation is making a difference in some parts of the world but seldom very quickly. Insofar as race and ethnicity are important motivators of political protest, particularly when allied to religious and language differences, ethnicity must play a key element in any analysis of inequality and its consequences.

**Social Class**

The June 15, 2006, issue of *The Economist*, in the article “The Rights and Wrongs of the American Model,” argued that inequality is acceptable providing that three conditions are met: “First, society as a whole is getting richer; second, there is a safety net for the very poor; and third, everybody, regardless of class, race, creed or sex, has an opportunity to climb up through the system.” Unfortunately, the signs are that in recent years
those conditions are not being met in most countries in the world. Insofar as access to work is determined by qualifications, those with a good education tend to get the best jobs. But access to education is a function of social class; richer parents can pay for a better education for their children, whereas poor parents cannot. Rather than equalizing people’s opportunities, therefore, too many educational systems are creating new forms of social class division and inequality rather than overcoming such divisions.

A Normative Conclusion

Starting in the late 19th century, and particularly after World War II, many governments across the globe created a form of welfare state. Led by Scandinavia and the United Kingdom, social safety nets were created, social security and minimum wages implemented, the quality of housing and health was improved, and universal education systems were established that would give everyone a chance of improving their lives. Social democracy was premised on the belief that social inequalities should be reduced. Of course, improvements were usually much more modest than anticipated, but social inequality did generally decline.

Arguably, that condition is no longer the case. Recent globalization and the rise of neoliberalism in the 1980s created immense new opportunities for the world’s rich, the well educated, and the opportunistic to make very large sums of money. The market regained much of the power that it had lost under social democracy. Governments either reduced their role, including reductions in social services, or found that they could not control the strength of market forces. As a result, inequality has surged after years of decline.

Alan Gilbert

Further Readings


Informal Economy

Informal economy—also referred to as the “unorganized,” “unprotected,” or “unregistered” sector—is a process of income generation that is unregulated by the political institutions of a society, in a legal and social environment in which similar activities are regulated.

The absence of institutional regulation in the informal economy affects various elements of the work process. First, it influences the status of labor, which may be undocumented, working below minimum wage, lacking social benefits, or employed under circumstances that legal or societal norms would not otherwise allow. Second, it influences the conditions of work under which labor is employed, which may involve ignoring health, hygiene, and other safety requirements. Third, it refers to a particular form of institutional management. For instance, a company may engage in systematic fiscal fraud or the generalized use of unrecorded cash payments as a means of economic transaction. Scholars of the informal economy emphasize that there is no theoretical
reason to exclude the unrecorded practices of large corporations from the informal economy since they are closely linked with the growth of other informal activities. In a seminal collection of articles titled The Informal Economy: Studies in Advanced and Less Developed Countries, Alejandro Portes and Manuel Castells emphasized the existence of an informal economy in all countries by including case studies ranging from New York City and Madrid to Uruguay and Colombia. This perspective reinforces that the informal economy is not a marginal phenomenon but a fundamental politico-economic process at the core of many developing and developed countries. The basic distinction between formal and informal economic activities does not hinge on the character of the final product but on the manner in which it is produced and exchanged. Articles of clothing, restaurant food, meat, fruits, and vegetables, for example, are not illicit commodities, but they may have their origins in legally regulated or unregulated production arrangements.

Characteristics of the Informal Economy

The social and economic characteristics of the informal economy cannot be captured by a strict definition, but existing evidence does lend itself to a limited number of generalizations. First, the informal economy is universal and can be found in countries and regions at very different levels of economic development and industrialization. Indeed, in the current context, the informal sector continues to grow even in the highly institutionalized economies of North America and Western Europe. Research on the topic is more difficult in these contexts because these activities are categorized as clandestine and therefore more actively persecuted. Second, since the forms adopted by unregulated production and distribution vary widely even within single societies, this sector is extremely heterogeneous. Third, there is agreement among researchers working on the informal economy that the sector has grown in size in many different social and economic contexts in the past few decades. Brisk population growth, increasing landlessness, inadequate social support programs, and growing rural-urban migration are presumably some of the factors that have ensured that large enterprises are unable to create enough jobs to absorb the swelling supply of labor. Under such circumstances, increasing numbers of urban and rural people have been forced to, or have chosen to, create alternative sources of employment. All such unregistered, and therefore unrecognized, manufacturing, service, and petty trade activities are also collectively known as the informal sector—the sector of economic activity that is not registered with government agencies and does not comply with regulations governing labor practices, taxes, and licensing. In India, for example, the informal sector is estimated to account for 93% of the total labor force and 64% of the gross domestic product.
Because it is inaccurate and unjust to describe such a large dynamic workforce in terms that relegate it to a peripheral position, many authors and activists prefer to use the term *self-employed*, arguing that these workers are essentially entrepreneurs since they assume all the risks of their businesses. The term *self-employed* seems appropriate to describe people who attempt to generate independent livelihoods under a variety of circumstances, compared with other terms with pejorative connotations, such as *casual* work, or illegal connotations, such as *black economy*, derived from the Italian *lavoro negro*, traditionally used to describe people with connections to the mafia, or *marginal* economy, which utterly fails to capture the significant economic contributions of the sector. The concern some researchers express about the use of the term *self-employed* arises from the possible confusion of the meaning attributed to it by Western capitalism. Self-employment in the context of the industrialized world may imply informed choice to pursue independent livelihoods in the presence of other opportunities. An overwhelming number of people in the developing world as well as some vulnerable groups such as undocumented workers in developed countries are driven to the informal sector not out of a desire to be entrepreneurial but because of lack of options and unmet household subsistence requirements. The absence of a fixed employer, or the difficulty of identifying one due to elaborate chains of subcontracting, is a common characteristic of this sector and one that ensures that workers remain in precarious casual, contractual, migrant, or home-based work environments. While flexibility in working hours and in locations of work is perceived as an attractive option in the formal sector, for socially vulnerable groups it usually translates into undesirable working conditions. Home-based informal-sector workers, for example, frequently work longer and harder hours than formal-sector workers but fail to avail themselves of any legal entitlements for minimum wages or social security benefits, sometimes despite the existence of protective legislation. Hidden but effective structures of dependency make it difficult to supply the evidence needed to prove that the real nature of the relationship between many of the informal-sector workers and those who pay for their work is one of employees and employers.

The informal economy simultaneously encompasses many contradictions within different geographical and cultural contexts: flexibility and exploitation; productivity and abuse; aggressive entrepreneurs and vulnerable workers; survival and greed. However, it shares three commonalities. First, research on the informal economy demonstrates its systemic connection with the formal economy. Home-based workers in Indian slums who sew Gap and Eddie Bauer shirt labels for local contractors and undocumented workers who work in meat-packing plants in the United States demonstrate that the informal sector is an integral component of national and global economies and not a marginal appendix to them. Second, informal-sector workers tend to receive fewer benefits and lower wages and experience worse working conditions than formal-sector workers. This is a prerequisite for their entry into the labor market. Third, although informal workers are frequently harassed, governments tend to tolerate and even stimulate informal economic activities in order to promote political patronage or resolve social conflict. This is as true in governmental attitudes toward “illegals” in North America or Europe as it is in the experiences of squatter settlements in the burgeoning cities of the global South.

*Bipasha Baruah*

**Further Readings**


Today, more people are exposed and have access to more information than anytime in the past. This situation results from the information economy. Easy access and ample exposure to information has reshaped modern societies, permeated everyday life, and now influences the decisions people make and the opportunities they seek. There are even world summits that solely address the issues of an information society. Yet not everyone has equal access to information, and geographic patterns of information access have emerged. In effect, areas of higher economic development typically have greater exposure and access to information than lagging areas. This trend is true at the global, national, or regional scale. Some regions and urban places are tied to the information network to a greater extent than others, and such places tend to be sources for information.

The growth of an information society is tied heavily to information and communication technologies. The introduction of the telegraph helped collapse space in the 19th century. Ensuing developments in radio and phone technology furthered the collapse. Television has profoundly affected our ability to access information even to the point of it influencing how we might vote. Today, the Internet is one of the more viable avenues for accessing information. As information technology escalates in ingenuity and capacity, so does the ability of societies to effectively handle information and information flows. The Internet has become a popular way for businesses and institutions to interact with one another, for people to find information pertinent to their needs, or for converting information in hardcopy to a digital format. As such, modern societies have entered the digital age of information.

Not all societies have equal access to digital information. Those that are not fully enveloped within the information network typically have smaller national outputs, or fewer computers, televisions, and phones per person. Still, the ability to access information on the Internet and television or by phone has never been easier anywhere. The economic benefits that can accrue from information flows have for the most part reinforced existing spatial economic patterns. The Internet has not significantly reshaped spatial economies; if anything it has reinforced their structure. Those regions that are notably tied to a nodal center for economic leadership will continue to be so in the information age. As such, one might view information societies as hierarchically organized, with some people and regions having greater access to tacit information and being further up the hierarchy. Because of this hierarchical structure, it is not practical to view global information patterns as wholly ubiquitous.

Information patterns can be broken into different layers: that which is explicit (or easy to understand and open to public use); that which is tacit (or strategic and difficult to attain); and those layers in between, of which each will produce different geographic patterns. Explicit information patterns or flows will be much more ubiquitous over space than tacit information patterns. It is the concentration of strategic information that has led to truncation in spatial economies. Within information societies, selected cities have subsequently emerged as growth nodes.

Using Internet domains as a proxy for the development of information societies, it becomes clear that some countries and regions dominate. For example, around 45% of domains worldwide recently originated in the United States, and nearly 70% of all domains originate in one of seven countries. While the share of U.S. domains is decreasing, the top seven countries continue to hold around 70%. It is anticipated that as more countries adopt information technology and initiatives, the concentration and control of information patterns could widen. To what extent this happens will unfold in the next few decades.

Though information patterns are becoming somewhat diffuse geographically, it is difficult to parse out quality or tacit information from routine or background information. In the 1930s, Fritz Machlup and Joseph Schumpeter were among the first social scientists to examine patents as a source of knowledge and its distribution. The advantage of using measures of technology as a surrogate for tacit information is that one can isolate highly prized or guarded information. Furthermore, the location of patents can provide an accurate understanding of where key nodes of information exist.
The concept of information society has been compared with the knowledge economy, networked societies, postindustrialism, or the information revolution, to name a few. A commonality in these concepts is that modern societies are becoming increasingly dependent on information, information technologies, and information services. As societies transition from primary to secondary, to postindustrial societies, they inevitably acquiesce to an information society. In fact, the Organisation of Economic Co-operation and Development (OECD) measures the information economy based on the share of a country’s GDP (gross domestic product) that is based in this sector. This is done by measuring the amount of regional output that is not based on tangible or manufactured goods. All information societies place a higher premium on codification, infrastructure, and education. Codification enables regions to better manage information in meaningful and competitive ways to create what could be called managed societies. As societies become more information based, they are more apt to become more scientific, technological, and informed. What facilitates this trend, and at the root of an information society, are computers, phones, and other information and communication devices.

Those regions that adapt to being information based will benefit from their early entrance. Whether they can maintain their lead over other regions is contentious. Value-added information that is tradable creates wealth for regions and a new way of working for people. Knowledge and what people do with it is pertinent to the development of an information society. Those regions that foster creativity among their populations are more apt to benefit from an information economy. Added to this is a mobile, educated workforce that desires to live in advantageous locations. The footloose nature of the information economy enables populations to move to desired locations. Still, skilled labor patterns remain concentrated within the so-called footloose nature of the spatial information economy.

Brian Ceh

See also Castells, Manuel; Communications Geography; Cyberspace; Digital Divide; E-Commerce and Geography; Education, Geographies of; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Postindustrial Society; Producer Services; Space of Flows; Spatial Data Infrastructures; Telecommunications and Geography

Further Readings


INFRASTRUCTURE

Infrastructures are, and have been historically, the fundamental support network of society. This became apparent as urban populations and their densities rapidly increased during the 19th and 20th centuries. The developing complexity of commodity and information flows evident with globalization has also stressed the critical nature of infrastructure in today’s world. Infrastructure is the “hidden hand” behind urban development and nation building, enabling the flow of people and critical resources such as water, energy, waste, information, agricultural produce, and manufactured goods. At the same time, inadequate infrastructure provision, or the failure of infrastructure, generates considerable social disorder. In 2005, this failure was evident in New Orleans in the aftermath of Hurricane Katrina.

The term infrastructure was first used to define permanent military facilities, such as dry docks, bases, and airstrips. The meaning of infrastructure was eventually extended to include various other public and private works, including water and sewer networks, treatment plants, transportation systems, health, education, communication and computer networks, power systems,
sport stadiums, and arts centers. There are two distinct infrastructure types, interurban and intra-urban infrastructures. Interurban infrastructure connects cities into a national network, the national urban system, while intra-urban infrastructure connects homes and businesses within an urban center, enabling the functioning of a city as a system.

Despite its importance, infrastructure provision throughout the affluent West has become so normalized that it is generally taken for granted. In part, this status is a reflection of the effectiveness of these complex systems in providing crucial services. As argued by David Perry (1995), when infrastructures “work best, they are noticed least of all” (p. 2). In part, however, the increasing oversight of the importance of infrastructure in sustaining social order and quality of life has been facilitated by an important feature of contemporary infrastructure management, concealing infrastructure.

Maria Kaika and Erik Swyngedouw have argued that while through the early 20th century, infrastructure, and particularly urban infrastructure, maintained an important visual role in the urban landscape, being celebrated as technological advancements of modernization, its role within the urban setting was significantly diminished in the late 20th century. This move toward the invisibility of urban infrastructures has been achieved by closing down infrastructure facilities within cities (such as power plants and pumping stations) and sourcing out power, water, and other services from more distant locations. Greater invisibility of infrastructure has also been achieved by moving infrastructure beneath the city, making the urban underground a rich network of pipes, wires, conduits, and transportation networks. The $15 billion “Big Dig” in Boston, which took 15 years to construct, provides a recent example. The project involved the construction of 7.8 miles of highway, totaling 161 lane miles, with approximately half of the network built underground.

The Role of Government

In the United States, early links between public infrastructure investment and economic and political security were recognized by President George Washington and his Treasury Secretary Alexander Hamilton. However, it was not until Thomas Jefferson’s presidency that federal investments in infrastructure first became evident. Much of the early investment was placed on interurban infrastructure, canals, roads, and railways. However, in the mid 19th century, research in Britain by John Snow on water supply and cholera and the work by Edwin Chadwick on sanitation and public health placed a new importance on intra-urban infrastructures. In addition, by the late 19th century, a new emphasis on infrastructures within cities was also facilitated by rapid population growth, and the unprecedented urban densities, which began to be realized in the early industrial centers.

The role of government in the delivery of infrastructure is an important issue in infrastructure provision. Two unique characteristics of public infrastructure are recognized that distinguish these goods from private goods, hence their classification as public goods. Public goods are nonrival in consumption and nonexcludable. Nonrival means that once provided many can use a public good without loss of benefits to others and at minimum extra cost in maintenance. The lighthouse provides a classic example. Once provided, many ships can use the services of a lighthouse, and this use does not reduce the services of the lighthouse to other ships. This condition is very different from that of private goods, where the benefits of consumption are limited to the person consuming (e.g., the benefits of eating an orange are limited to the person consuming the orange, because once it is eaten, there is no orange left). Nonexcludability refers to the difficulty of excluding individuals from using public goods once they are provided. For instance, it is very difficult, or very costly, to exclude ships from using lighthouses. Because of nonrivalness and nonexcludability, private companies have little interest in providing public goods, and unless governments intervene, public goods will be provided at suboptimal levels, generating reductions in quality of life and economic performance.

Government intervention in the provision of infrastructure is also justified because of externalities. One type of externality occurs when the
The recognition of public goods and externalities in the provision of public infrastructure emerged through the early and mid 20th century, largely in response to the disorder and chaos brought on by early capitalism. Improvements in quality of life and social well-being following government intervention in infrastructure delivery—particularly apparent in addressing many of the stresses experienced by the large and rapidly growing industrial centers—illustrate the effectiveness of public infrastructure provision in simultaneously improving both equity and efficiency within cities.

In the late 20th century, a new philosophy and social movement emerged, neoliberalism, which advocated low taxes and minimal government in social and economic activities as a means of improving economic performance. Becoming politically entrenched in the United States following the election of Ronald Reagan as president in 1980, neoliberalism fundamentally altered the public role in infrastructure provision. Private market values and market incentives in the public realm, along with increased competition, public-private partnerships, and privatization became the new focus of government. The relevance of public goods and externalities in infrastructure provision was increasingly dismissed, with significant scaling back of government in the delivery of infrastructure. However, growing concerns over...
INNOVATION, GEOGRAPHY OF

For more than a century, geographers and economists have developed theories on the spatial agglomeration of economic activity in response to three empirical observations:

1. A large portion of world output is produced in a limited number of highly concentrated core regions.
2. Firms in similar or related industries tend to colocate in particular places.
3. Both of these patterns seem sustainable over time.

While this outcome has most often been attributed to agglomeration economies, some scholars have long pointed out that the economic and institutional fabric of some areas promotes innovative behavior that further reinforces this pattern.

The most lasting contribution among the early analysts is the economist Alfred Marshall’s “industrial districts.” Besides mentioning the external benefits that single-activity or closely related producers derive from sharing the fixed costs of common resources such as specialized
infrastructure and services, skilled labor pools, and specialized suppliers, Marshall emphasized that through colocation and frequent interaction, producers share a common knowledge base. By the middle of the 20th century, however, technological changes and the enhancement of labor and entrepreneurial mobility had led most regional growth and development scholars to conclude that “such local specialization . . . [had] become increasingly rare,” while, in contrast, “external economies on the broader basis of urban size and diversity [had] remained a powerful locational force” (Hoover & Giarratani, 1970, p. 121). This perspective, according to which innovative activities were seen as less relevant for industrial agglomeration, probably explains why, along with the development and/or refinement of analytical (mathematical) tools unsuited to the study of innovation, increasingly mechanistic and static “resources allocation” or “location-scanning” perspectives became dominant among analysts.

These theoretical approaches, however, proved unable to account for the spontaneous and spectacular rise in the 1970s and 1980s of numerous regions, from the Silicon Valley and Boston’s Route 128 (Boston) in the United States to the so-called Third Italy, Emilia-Romagna, whose main characteristics were the spatial clustering of related and highly innovative firms. Scholars in disciplines ranging from geography and political science to sociology, business management, and economics thus began to (re)discover and further develop more qualitative and dynamic concepts and insights to explain how the industrial and social characteristics of a given place (ranging in scale from streets and industrial districts to cities and regions) provide or fail to provide fertile soil for innovative behavior or, in other words, how some areas act as focal points for innovative activities. These contributions emphasized not only that colocation gives related firms greater flexibility and the opportunity to quickly adapt to sudden shifts in market demand but also that some places are better than others at integrating the formal and informal collective processes essential to the production of continual innovation. Despite early and constant criticism that this “spatial interaction literature” features a number of ill-defined and overlapping concepts or frameworks (from “industrial districts,” “innovative milieu,” and “clusters” to “learning regions,” “regional innovation systems,” and “techno-regions”), its main message has always been twofold: (1) Where prosperity exists, it is regionally based and (2) the sources of this prosperity are to be found in the regions themselves and not in some exogenous factors.

Questions in the Geography of Innovation

Fundamentally, the geography of innovation literature asks two questions:

1. Why are some regions more innovative than others?

2. How does a specific location matter for the continuous upgrading of firm capabilities?

The perspective in the former question is that of the region, whereas the latter proceeds from the firm perspective. The answers most commonly provided revolve around the importance of geographical proximity between actors, which greatly facilitates formal and informal collaborations between firms (be they potential competitors or in a user-producer relationship) and/or between firms and research institutions; the spin-off of new firms; and the transmission of tacit knowledge (through face-to-face interactions and the interfirm mobility of skilled workers). Each factor is now examined in turn.

Local Linkages and Collaboration

Geographical proximity, because of the frequent interactions and long-term contracts or commitments among people that it allows (whether in working environments or in social activities), is said to often play a crucial role in building the trust bonds that are needed to share sensitive information and to develop a successful customer-supplier relationship.

Spin-Off Formation

Entrepreneurship, especially in terms of employees creating new firms in close proximity
to former employers (so-called spin-offs or start-ups), is said to be greatly facilitated in some regional contexts. On the one hand, an entrepreneurial culture in which individuals continually leave their employers to launch new firms provides ample demonstration effect, which further reinforces this tendency. On the other, localized industries provide easy access to specialized labor, inputs, and knowledgeable investors, which further facilitates the launch of innovative firms. Spin-offs also tend to create a local or regional environment where firms and individuals interact more with each other than would otherwise be the case.

**Tacit Knowledge**

The more specialized and innovative an activity is, the more it is likely to be geographically concentrated. The more standardized it becomes, the more it tends to migrate toward customers or inputs. This pattern can be attributed in part to the fact that the crucial knowledge in any innovative industry is not standardized information, routine patterns, or the public knowledge of science but rather what is new, what are the latest changes, and the specialized knowledge that individuals have acquired through practice and mistakes. Thus, knowledge from which innovations stem is not freely available, which in turn provides firms that locate near its sources a competitive advantage. As such, globalization and improvements in telecommunication technologies have not crowded out the need for proximity but have conversely strengthened it in cases where crucial knowledge is only locally available. In short, geographical proximity between related firms is said to increase the concentration of knowledge spillovers and the speed of information flows. Even though most of the suppliers and customers of a firm might be located outside its regional setting, being located in a specific area typically allows creative and entrepreneurial individuals to absorb thinking processes, along with specialized vocabulary and ways of doing things, while increasing the probability of useful informal encounter. It also makes it easier for entrepreneurs, managers, and technicians to avoid being caught off guard by unanticipated breakthroughs by allowing them to monitor emerging technologies closely and to find answers to their questions more rapidly.

While the case on behalf of the geographical base of innovation is strong, it should perhaps be handled more cautiously than it often is for reasons ranging from the fuzziness of the main concepts used in this literature, the continued importance of both traditional agglomeration economies and nonregional networks and linkages, and the fact that individuals were born in or like a particular location.

*Pierre Desrochers and Samuli Leppälä*

See also Agglomeration Economies; Business Cycles and Geography; Economic Geography; Education, Geographies of; Factors Affecting Location of Firms; Incubator Zones; Industrial Districts; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Technological Change, Geography of

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**Further Readings**


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**INPUT-OUTPUT MODELS**

Developed by Wassily Leontief in 1936, input-output models are an alternative to simple economic base and Keynesian approaches to modeling an economic system. Essentially, the models are used to describe and analyze forward and
backward economic linkages between industries. They compile the industrial activity of an economic system into an input-output table that is built around a matrix of monetary transactions. These transactions can be recorded by industry or sector, which are groups of industries involved in similar production processes.

The basic principle of input-output models is that the products sold (outputs) from one industry are purchased (inputs) in the production process by other industries. Therefore, it is plausible that a change in one interindustry linkage can affect the entire system of linkages. For example, the steel industry uses inputs of coal (outputs from the coal industry) to produce goods. These goods are then purchased as inputs in production by other industries, such as the construction industry. What would the impact of a rise in demand for goods produced by the steel industry be on the construction industry, other industries, and the entire economic system? An input-output model could be developed to address these interindustry interdependencies. This type of information provides geographers with a disaggregated view of an economic system in that industries are connected on the basis of buyers and sellers.

Data on the economic linkages between industries are typically collected from surveys of the economic system being modeled and compiled in a table. The table is constructed around a matrix of monetary transactions. The transactions that take place between industries represent a flow of goods and services. They are tabulated based on the value of sales (outputs) and purchases (inputs) of intermediate goods between industries. Like any table, an input-output table consists of a series of columns and rows. The rows of the table reflect the value of sales (outputs) made by each industry. Sales can be further divided to represent sales to final demand. In these categories are included sales of output made to the consumer (households), sales to government (local, state, federal), sales of investment goods (capital equipment), and sales destined to be outside the economic system being modeled (exports). The columns of the input-output table reflect the value of purchases (inputs) that are made by each industry. Purchases can be further divided to represent purchases from value added and purchases of imports. In these categories are included returns to capital (profits and dividends), labor costs (wages and salaries), and purchases of inputs made from outside the economic system being modeled.

Establishing general forward and backward economic linkages between industries is fairly simple with input-output models (see Table 1). In locating the value of sales (outputs) and purchases (inputs) in the table, it is necessary to become familiar with the intersection of rows and columns and what each represents. Consider a linkage between Industries X and Y, with Industry X as the seller. To find the value of sales made from Industry X to Industry Y, locate the selling Industry X along the left side of the table and then read across to find the purchasing Industry Y at the top of the table. This would show the value of outputs that are sold from Industry X to Industry Y. Following the previous example, now consider Industry X as the purchaser. To find the value of purchases made by Industry X from Industry Y, locate the buying Industry X along the top of the table and then read down to find the selling Industry Y along the left side of the table. This would show the value of inputs that are purchased by Industry X from Industry Y. Essentially, one-way or multiway economic linkages among industries are possible with input-output analysis. However, analysis of more complicated linkages requires knowledge of matrix algebra.

Input-output models have varying degrees of openness and closure, meaning that there is no

<table>
<thead>
<tr>
<th>Selling Industry</th>
<th>Purchasing Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>X(1)</td>
<td>x_{11}</td>
</tr>
<tr>
<td>X(2)</td>
<td>x_{21} x_{22}</td>
</tr>
</tbody>
</table>

Table 1  Basic input-output table showing general forward and backward linkages between Industries X and Y

Source: Author.
guideline set for determining how many categories of economic activities, final demand, and value are added to include or exclude when developing the model. This largely depends on the analytical purpose of the model. Its use has been extended from the most basic, describing interindustry relations, to include more in-depth and technical analyses of economic systems. Applications of the model include, but are not limited to, forecasting and planning scenarios, economic and policy impact analysis, feasibility studies, and sensitivity analyses. Each of these analyses requires a mathematical manipulation of the transactions table. Commonly, input-output models are used as an alternative to simple economic base and Keynesian models to measure the impacts of multiplier effects within an economic system. With this application, input coefficients that are derived by dividing the purchases in an industry into proportions of total purchases are mathematically altered to represent direct and indirect industry multipliers. The input coefficients can be manipulated to reflect industry-to-industry multipliers in terms of employment, income, and industrial output. For example, in what way does an increase in demand by Industry Y for a good produced by Industry X affect the output of Industry X? However, it should be noted that there are many methods that can be used to calculate economic multipliers from the input-output table.

Regardless of the analytical purpose of input-output models, modeling of an economic system can be undertaken at various scales of geographical inquiry, such as national, regional, state, and metropolitan. In some instances, firm-to-firm interdependencies have been established. Additionally, analyses have compared interindustry relationships across scales so that national, regional, state, and metropolitan economies are compared with other economies at similar geographical scales. To that end, input-output models have been used to help make economic policy decisions.

Todd Sink

See also Economic Base Analysis; Economic Geography; Location Theory; Models and Modeling; Regional Economic Development

Further Readings


For some 60 years, the Institute of British Geographers (IBG) has been the United Kingdom’s leading learned society for geographers. It was founded in 1933 and merged with the Royal Geographical Society in 1995.

Learned societies play several major roles in the production and diffusion of knowledge. To promote research, they organize conferences, publish journals, and fund projects; to promote their disciplines, they represent them in a range of arenas. Until the establishment of the IBG, academic geographers in the United Kingdom had no such organization. They were able to meet and publish through the Royal Geographical Society (RGS), the Geographical Association (GA), and the British Association for the Advancement of Science (BA), but each of these had a much wider brief than just supporting academic geography. The GA’s mission is to promote geographical education at all levels, and most of its attention focuses on the country’s school systems, where it has been an extremely successful advocate for and a change agent in geography. The RGS is a well-established London society that did much to promote geography (especially exploration, discovery, and cartography) and geographical education in the 19th century; by the late 1920s, however, academic research (especially in human
geography) was marginal to its concerns. The BA’s annual conferences provide a venue where academic geographers can meet in their separate section, but this body’s raison d’être and membership is also much wider than that of an academic learned society.

**Founding and Early Years**

Geography was a very small discipline in U.K. universities in the 1930s. Few departments had been established in the 19th century, and the first full honors degree was not launched until 1917. By the end of the 1930s, virtually every university and university college had a small department—more than five permanent staff members was a rarity. Teaching loads were both heavy and broad, and research activity was not put at a premium. Nevertheless, several meetings—organized by a small group based in University of London colleges—determined that university geographers needed a separate society to organize meetings at which research discussions would predominate and to offer a publication outlet, hence the IBG’s establishment. It held an annual residential conference (usually just after the New Year) from the start plus occasional field meetings, and in 1935, it launched its publication *Transactions and Papers of the Institute of British Geographers*.

**Growth of the Organization**

Until after World War II, the organization was small and its operations limited. Officers were elected, but the tradition of an annual presidential address was only instituted in 1948. More important, *Transactions* did not develop as a regular serial publishing refereed academic papers until 1946. Before that, it published only six separate monographs plus reports of the Institute’s annual conferences. In 1959, the Institute organized the first of its international seminars—on applied geography—in Poland. These were used to promote international contacts, most of them with geographers in countries behind the Iron Curtain, although there were also series of Anglo/German and Indo/British seminars; after 1989, the range of countries widened, but the seminars became less necessary as international travel to major conferences became much easier.

Geography student numbers grew rapidly in the United Kingdom after 1945, and university departments expanded accordingly. The annual conference attracted more participants, and *Transactions* became a regular refereed serial, appearing only once per year until 1962. It became a quarterly in 1976 (when it was relaunched as a “New Series”). A second journal—*Area*, which evolved out of a newsletter—was established as a quarterly journal in 1969. The Institute also sponsored a book series, comprising monographs and major edited collections, in conjunction with commercial publishers.

During the 1960s, reflecting the growth in the number of practicing academic geographers, including graduate students, a major change took place in the IBG’s organizational framework with the creation of separate study groups, most of which focused on specific areas of the discipline. Until then, the annual conference had comprised the presentation of unrelated papers, and moves to hold symposia on specific topics were among the stimuli for the study groups. The first was the British Geomorphological Research Group (now the British Society for Geomorphology, which is affiliated with the Geological Society of London as well as the RGS), followed soon after by a Population Studies Group (whose initial raison d’être was producing an atlas using 1961 census data) and an Urban Geography group. These enrolled members from both among the Institute’s membership and beyond obtained subventions from IBG funds. They organized sessions at the annual conference, plus separate 1-day and residential symposia and other meetings; they generated publications (including monographs, conference proceedings, and, in a few cases, new serials); and they promoted research through allocations of small funds. At about the same time, reflecting its expanding membership and activities, the Institute established a permanently staffed office in London (housed in the RGS building).

The number of study groups (renamed research groups after the 1995 merger) grew rapidly.
INTERGOVERNMENTAL ENVIRONMENTAL ORGANIZATIONS AND INITIATIVES

The environmental issue area is notable for its multiplicity of intergovernmental organizations, numbering nearly 200, with new ones regularly created. Although the United Nations (UN) is a central player in organizing and overseeing many international environmental regulations and initiatives, international environmental governance is conducted largely through organizations created to address specific environmental problems.

The Role of the United Nations

Various organizations within the UN play roles in global environmental governance. The most
central of these is the United Nations Environment Programme (UNEP), a specialized agency of the UN, founded in 1972. UNEP’s mission is to play a catalytic role in environmental governance, coordinating environmental efforts by other UN agencies. It has played active roles in environmental monitoring and scientific research on environmental issues and has coordinated and supported the negotiation of international environmental agreements or conventions (treaties). It has also undertaken specific programs to address international environmental issues. Notable among these is its regional seas program, which has negotiated agreements involving 140 states to protect 13 regional seas.

The UN has also held major international conferences on issues relating to environmental issues. The two most influential of these conferences were the United Nations Conference on the Human Environment (UNCHE), held in 1972 in Stockholm, and the United Nations Conference on Environment and Development (UNCED), held in 1992 in Rio de Janeiro. UNCHE involved representatives from 113 states and numerous nongovernmental organizations (NGOs). It produced a Declaration, an Action Plan, and several resolutions, including one that advocated the creation of UNEP.

UNCED focused on the relationship between environment and development. It was attended by representatives of 178 states and featured a parallel “Global Forum” where representatives of 1,500 NGOs met. The conference reiterated the right of states to development and to sovereignty over their natural resources and prioritized the generation of additional financial resources to assist countries with environment and development needs.

Other UN environmental initiatives are worth noting. The World Commission on Environment and Development was established in 1983 at UNEP’s recommendation. It produced the report Our Common Future in 1987 to give an overview of the difficulties facing the intersecting desires for economic development and environmental protection. The Commission on Sustainable Development was created in 1992 following a recommendation from the Rio Conference. The Millennium Development Goals attempt to improve the lives of people in developing countries in specific ways by 2015. One goal specifies the need to “ensure environmental sustainability.”

### International Environmental Organizations

Most intergovernmental environmental cooperation takes place within issue-specific institutions created to address individual environmental problems through specific measures. Each organization has, for the most part, been created through its own negotiation process (usually in the context of a specific treaty). That process results in an anarchic pattern of institutions, where multiple institutions may address different aspects of a given problem or different types of solutions and each organization has a different set of member states.

The earliest intergovernmental institutions focused on what we would now call the sustainable use of species, such as seals, birds, whales, and fish. Different organizations were created to restrict hunting of a given species to a level that would allow reproduction and the indefinite continuation of human use of these resources. These organizations tend to be fairly narrowly focused on a given one or more closely related species, often in a specific region. Examples of existing organizations with this function include the International Whaling Commission and a large number of Regional Fishery Management organizations, which restrict fishing behavior in multiple organizations that focus on species, region, or both.

A different set of organizations addresses the protection of endangered species in a slightly different way, with a focus on preventing extinction and less concern about ensuring continued human use of the species. The two most important organizations of this type are the organization that oversees the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the one for the Convention on Migratory Species. In addition, a UNEP-run secretariat oversees the Convention on Biological Diversity, a process that involves protecting the overall diversity of species and ecosystems.

The International Maritime Organization (IMO) oversees most of the international regulation of
ocean pollution and safety. The IMO issues codes and recommendations to its members and also sponsors intergovernmental conferences leading to the negotiation of binding multilateral conventions on maritime matters, the implementation of which it then oversees.

Other organizations address atmospheric issues. The United Nations Economic Commission for Europe negotiated and implemented multiple agreements to decrease acid rain in Europe. The Ozone Secretariat oversees implementation of the international agreements relating to the protection of the ozone layer. More contentious and less successful so far are international efforts, under the Kyoto Protocol, to decrease emissions of the greenhouse gases that contribute to climate change.

Other intergovernmental environmental institutions are those that address collective action on regional issues, including the Antarctic and the Arctic, and institutions addressing wetlands, desertification, and transboundary movement of hazards, among other issues.

What these intergovernmental institutions have in common is that each is created to address a specific environmental problem. There are similarities across organizations. Many include scientific bodies that are separate from decision-making bodies; most either require unanimous decisions for major policy changes or allow states to opt out of decisions with which they do not agree, and almost all make their primary decisions through regular meetings of the parties. There are linkages between them, sometimes negotiated by necessity, as overlapping mandates can otherwise create conflict or confusion. But, overall, most intergovernmental environmental governance is still done through fairly separate organizations, concerned collectively with natural resources or pollution but addressing these issues through distinct institutional structures.

Elizabeth R. DeSombre

See also Climate Policy; European Green Movements; International Environmental Movements; United Nations; United Nations Environmental Summits; United Nations Environment Programme (UNEP)

Further Readings


INTERNATIONAL CRIMINAL COURT

The International Criminal Court (ICC) is the world’s first permanent body established to prosecute genocide, crimes against humanity, war crimes, and aggression. The creation of the ICC was the result of decades of advocacy and campaigning by human rights activists, compromises between nation-states, and transformations in the international political order. The hope attached to the ICC is that a permanent court, capable of prosecuting the most powerful perpetrators on the planet, will prevent future atrocities. The ICC’s jurisdiction theoretically extends to the entire globe but in practice is subject to intense geopolitical power. The ICC must also navigate complex relationships with nation-states and the local communities most directly affected by extreme violence. The ICC is an intensely interesting phenomenon from a geographical perspective. It is both a product and a producer of globalization—an agent of geographical transformation as well as a result of such processes.

The international community has been imagined to be a superior space for holding perpetrators accountable, as local and national politics repeatedly protected the powerful—a condition referred to as impunity. The observation that “a person stands a greater chance of being tried and judged for killing one human being than for killing 100,000” highlights the dilemmas of accountability in the wake of mass atrocities. Although it is the powerful who are in a position
to commit genocide, and other massive forms of violence, that same power often protects them against prosecution. Proponents of the ICC have argued that conducting trials “elsewhere” provides a “spatial fix” in that international courts may circumvent and therefore overcome local impunity. While courts distant from the location of the atrocities (and outside the national jurisdiction) might prove capable of holding the most powerful perpetrators accountable, critics of doing justice from “afar” argue that the proceedings may have less relevance for the local communities and present troublesome issues concerning national sovereignty.

**Historical Background**

Interest in a permanent international body devoted to prosecuting war crimes has been expressed at various points in history. During the political polarization of the Cold War period, the superpowers blocked the establishment of an independent international institution devoted to prosecuting war crimes. As the Cold War moved toward its closure (1989–1991), interest returned in the form of a proposal to prosecute drug trafficking in the Caribbean as an international crime. Although the proposal drifted, the idea of an international court remained in the air. Violence during the breakup of the former Yugoslavia spurred the establishment of a war crimes tribunal in 1993 (the International Criminal Tribunal for the former Yugoslavia [ICTY]), and a second tribunal was established following the genocide in Rwanda in 1994 (the International Criminal Tribunal for Rwanda [ICTR]). Subsequent courts were established in Sierra Leone and Cambodia.

While there is a relative consensus concerning the establishment of these ad hoc tribunals, certain powerful sectors remained averse to a permanent international court that would have jurisdiction over every potential perpetrator on the planet. Among those objecting were the likely subjects—the notoriously violent dictators and despots who had every reason to resist judicial accountability. Objections also came from the U.S. government, which expressed fears that submission to the jurisdiction of an international court would undermine U.S. sovereignty and its potential for global military activity. While the United States had supported “international justice” for the peoples of Rwanda, the former Yugoslavia, Sierra Leone, and Cambodia, it was far less willing to consider such courts for its own nationals.

**Formation of the ICC**

The situation came to a head during the conference held in Rome in 1998 to draft and approve a statute for an international criminal court. For 5 weeks, the U.S. delegation to the United Nations (UN) conference wrestled with the rest of the world over the ICC treaty. Washington strenuously objected to elements in the treaty that gave the ICC its powers and, in the minds of the vast majority of the other participants, made the court viable. The United States insisted on conditions that would essentially make it impossible to try an American. Frustrated delegates worried that the resultant ICC would be either weakened by “American exceptionalism” or weakened by the lack of involvement of the United States.

Certain accommodations and compromises were made in an attempt to bring the United States on board. The principle of “complementarity” was among the most significant. Complementarity assures that national jurisdictions have the first obligation to prosecute. It is only when a nation-state proves “unable or unwilling” to prosecute its suspected criminals that the ICC can assume jurisdiction. In a world with less impunity, Colombian national courts would prosecute Colombians, Burmese courts would prosecute Burmese, and so on. But if national courts fail, the ICC is there to act.

A further restriction on the ICC’s powers is the restricted ways in which a case can be brought to the ICC. There are three “trigger” mechanisms that allow the ICC to take up a case. A case can be heard pursuant to

1. a state party referral (a party to the Rome Statute requests the ICC’s intervention);
2. a Security Council referral; or
3. *proprio motu*, in which the prosecutor may initiate investigations on the basis of information on crimes within the jurisdiction of the court.

In particular, allowing the Security Council a veto over the court, as the Security Council can effectively shut down an investigation/prosecution by ordering the ICC to abstain from such action for a year (renewed on a yearly basis), effectively provided the United States with the ability to shut down any case. Despite these appeasements, the United States became increasingly isolated, watching as its allies coalesced into the group of “like-minded nations.”

A notable aspect of the formation of the ICC was the role of international nongovernmental organizations (NGOs). International social movements were essential to the creation and promotion of the ICC. A group of more than 800 NGOs established the Coalition for the International Criminal Court and participated at unprecedented levels in the drafting of the Rome Statute, the lobbying of state parties, and the hard, grassroots work of bringing diverse national constitutions in line with international aspirations regarding human rights norms. Additionally, victims were to have a greater role both in the prosecution and in terms of the possibility of receiving reparations, provisions supported by the NGOs.

When the Rome Statute was drafted and approved in 1998, most observers close to the process believed that it would actually take many years (decades) for the ICC to materialize. In fact, the process moved quite quickly to fruition. By 2002, the Rome Statute had garnered the requisite 60 signatories and came into effect. The Dutch government agreed to host the offices of the ICC in The Hague, a city with an established community of international institutions. The Dutch government also provided substantial financing for the ICC’s infrastructure and passed national legislation associated with the presence on its territory of suspected war criminals and others who would be participating in such trials. In its gestation, the ICC also benefited from its location in The Hague in that many of the staff had significant expertise and experience from working in the ICTY.

When the ICC started in 2002–2003, its staff was extremely conscious of the vulnerability of the institution. At the ICC’s first major press conference in July 2003, the chief prosecutor sought to explain how the fledgling court was going to proceed among a universe of possible crimes. Extreme violence was found everywhere, but what to count as legitimate warfare and what to declare a crime against humanity? The ICC in its initial statements stuck to careful ground, narrowly interpreting its jurisdiction and stressing the limits of its resources. Temporally, the ICC’s jurisdiction covered crimes committed after it came into effect, which meant that any crimes committed before July 2002 were off limits. But by far the question of how the ICC would act spatially—how it would interpret its territorial jurisdiction—was the most provocative. In theory, the ICC is distinct in that it can exert jurisdiction (with justification) anywhere on Earth. This is its promise as well as its problem. Its very strength—its universal reach—is also the source of the enmity it has attracted.

### Impacts of the ICC

In its first 5 yrs. (years) of operation, the ICC can be analyzed through the lens of its actions and its omissions—cases taken and others ignored or rejected. The most obvious issue is that the four cases taken in the first 5 yrs. have all been in Africa: Uganda, the Democratic Republic of the Congo (DRC), Sudan, and the Central African Republic. That all 12 indictees are African men has raised charges of neocolonialism. There are concerns that the ICC is yet another version of “victor’s justice” in which the powerful (in this case the wealthy “Western” nations, which dominate the institutions of the international community, including the permanent members of the UN Security Council) use institutions such as the police and judiciary to criminalize the actions of the weak while simultaneously legitimizing their own violence. Of its omissions, the ICC controversially rejected requests to investigate alleged crimes in Iraq.

The ICC has been lauded as the culmination of millennial aspirations for justice and the future protection of human rights. Yet, to date, the
"international" court has indicted only African men. Granted, these suspects are accused of heinous violence—rape, child abduction, forcing family members to kill each other—documented in detail by reputable human rights watchdog organizations. Yet their violence and alleged crimes exist alongside those of the state, which happens to be the same authorities that cooperate with the ICC. In the case of Uganda, the prosecutor has investigated and indicted the bizarre, reclusive, and quite possibly insane Joseph Kony of the Lord’s Resistance Army but has (to date) ignored the violations committed by the Ugandan State. With the exception of an investigation into the actions of Sudan’s president, the ICC failed to challenge state-power.

As of 2009, 139 states had signed, representing all regions of the world, including 11 in Asia, 41 in Africa, 26 in Latin America and the Caribbean, 44 in Europe, and 22 in the Middle East and North Africa, as well as Canada, Australia, New Zealand, and several Pacific Ocean states. Future issues associated with prosecuting and preventing atrocities will likely exhibit complex, overlapping, and intertwined geographies. International institutions are proliferating, but local and national politics and social movements remain intense; rather than “overshadowed” by the international, local and regional practices seem fully engaged and inflamed. The ICC’s activities (and its absences) during its gestation and infancy illustrate complicated social, political, and legal geographies.

Amy Ross

See also Crime, Geography of; Genocide, Geographies of; Justice, Geography of; Law, Geography of; Social Justice; Transnationalism

International environmental movements are social movements that contest, at an international and sometimes global scale, different kinds of global environmental degradation. They try to show that this degradation is largely the result of current patterns of production, consumption, transportation, and energy use and, more generally, the prevailing organization of social life and the present international economic and political order. In arguing that global environmental degradation is one of the “routine consequences of modernity,” many international environmental movements challenge the very basis of modern society. International environmental movements are important because they define problems, propose solution strategies, and raise social consciousness with respect to global environmental problems such as climate change, biodiversity loss, deforestation, and desertification.

This entry describes the origin and development of international environmental movements, presents several examples of international environmental movement action campaigns and actors, and briefly sketches the context in which international environmental movements operate and the structure of international political opportunities.

Origins and Development

Environmental movements originally constituted one specific part of the “new social movements” that emerged in Western Europe and the United States from the late 1960s onward. Other examples of new social movements include the women’s, peace, and human rights movements, as well as the anti–Vietnam War and civil rights movements in the United States. New social movements distinguished themselves from “old” movements such as the labor movement by their emphasis on “postmaterialist” rather than materialist values; by their predominantly “new middle class” constituency; by their decentralized rather than hierarchical organizational structure; by their distrust in traditional, established ways

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of doing politics; by their unconventional action forms; and, finally, by their orientation at the development of new individual and collective identities. New social movements pointed to the “dark sides” of progress, environmental degradation being the most important case in point.

From the 1960s onward, environmental problems have been defined on an ever larger geographical scale: local, national, regional, and global. In the 1960s, local environmental movements typically struggled against polluting factories, new motorways, and the illegal dumping of waste. In the 1970s, movements struggled against the plans of national governments to build new nuclear energy plants and in favor of strong national legislation to halt the pollution of air, water, and soil. From the 1980s onward, environmental movements discovered the transboundary character of environmental pollution, for instance, acid rain, and started to plead for stronger regional (e.g., European) solutions. Finally, from the 1992 United Nations Conference on Environment and Development (UNCED) onward, the global character of many environmental problems was acknowledged: climate change, biodiversity loss, deforestation. UNCED brought together thousands of environmental groups from all over the world: It enabled the growth of contacts between these groups, which was reinforced by the facilities offered by the developments in telecommunication (e-mail, Internet).

Action Campaigns and Actors

Antinuclear Movement

One of the first international environmental movement campaigns was the Western European movement against nuclear energy in the 1970s and early 1980s. Around 1970, many Western European governments had decided to build substantial numbers of (new) nuclear power plants in order to decrease their dependency on oil for electricity generation, and in all those countries antinuclear movements arose. These movements showed striking similarities to the ideal type of a new social movement as described above. The reasons for resistance, for instance, could be labeled as “postmaterialist,” although they widely differed from one country to another. In some cases, a nuclear plant was considered to threaten the character of the local community and thus to decrease local autonomy. In other cases, nuclear energy and nuclear weapons were seen as different sides of the very same coin. Additional reasons for resistance included the fear of militarization of society due to the ever stronger measures to protect nuclear plants, the unsolved problem of nuclear waste, the resistance to capitalism, and so on. Antinuclear movement activists disproportionately emerged from the “new middle class”; they organized themselves through autonomous local networks, distrusted institutional politics, and fought their case through road blockades, tent camps, and (sometimes) violent confrontations with the police. Activists from different countries struggled shoulder to shoulder, resulting in the development of new, international, and “countercultural” individual and collective identities.

Movement Against Genetically Modified Organisms

The first truly European, or European Union (EU)-wide, international environmental movement was the movement against genetically modified organisms (GMOs). From the mid 1990s onward, seed companies such as Monsanto had tried to introduce genetically modified soy and maize in the European market. Although biotechnology companies and parts of the food sector claimed that consuming GMOs would become inevitable, international environmental NGOs such as Greenpeace and Friends of the Earth organized a massive resistance movement against them. The result was an EU-wide moratorium that lasted until 2004, and public opinion surveys reveal that time and again a vast majority of the European public rejects genetically modified food and feed.

The movement against GMOs consisted of three sectors from society: environmental groups, consumer groups, and farmers. Due to this broad constituency, the movement was able to tap not only into numerous specialized issue publics and their social networks (e.g., organic farmers’ associations) but also into more diffuse constituencies (e.g., supporters of Greenpeace). The success of
the campaign, however, widely differed from one country to another. In France, for instance, the two most important mobilizing groups were Greenpeace France and the farmer’s organization Conféderation Paysanne (CP), and this cooperation turned out to be very successful. CP's fame reached its peak following the August 1999 destruction of a McDonald’s franchise in Millau and the mediagenic performance of its charismatic leader José Bové.

The success of the campaign in France, and also in countries such as Italy and Spain, can be explained by the fact that GMOs were discursively linked with the expansion of neoliberalism, the increase in scale, and the accompanying loss of autonomy, values, and culture for small farmers. GMOs were brought on the market by multinational corporations such as Monsanto in a period when this kind of company was considered among the largest and most greedy beneficiaries of neoliberalism.

Another impact of the European movement against GMOs was the establishment of the “Network of GMO Free Regions” on November 4, 2003. On that day, the ministers of agriculture from 10 European regions, including Upper Austria and Tuscany, signed a document asserting the right of regions to forbid GMOs within their territories. The network has since grown to include 39 major regions from six different countries: Austria, France, Greece, Italy, Spain, and the United Kingdom.

**The Greenbelt Movement**

An example of a Southern international environmental movement is the Greenbelt movement. The Greenbelt movement provides income and sustenance to millions of people in Kenya through the planting of trees. It also conducts educational campaigns to raise awareness about women’s rights, civic empowerment, and the environment throughout Kenya and Africa. The movement was founded by Wangari Maathai, winner of the 2004 Nobel Peace Prize.

**Global Environmental Justice**

Other present-day international environmental movements include those against the international trade in toxic waste, the destruction of tropical rain forests, and climate change. The campaigns of these movements are increasingly framed through the perspective of “global environmental justice.” Although most actions take place at the local, regional, or national level, these actions are typically coordinated by international or global networks: the Basel Action Network (BAN), the Rainforest Action Network (RAN) and, most important, the Climate Action Network (CAN).

**The Climate Action Network**

The CAN consists of more than 365 environmental groups working to promote government and individual action to limit human-induced climate change to ecologically sustainable levels. Member groups include national branches of international environmental NGOs such as Greenpeace, World Wide Fund for Nature (WWF), and Friends of the Earth International (FoEI) and also local and regional organizations. CAN members work to achieve their goals through the coordination of information exchange and NGO strategies on international, regional, and national climate issues. Strategies vary from building a dike consisting of sandbags around the conference center where the 2000 UN Climate Summit was held, to lobbying government in favor of national-level climate laws, to solar energy demonstration projects. CAN has 7 regional offices that coordinate these efforts in Africa, Central and Eastern Europe, Europe, Latin America, North America, South Asia, and southeast Asia.

**International Environmental Movements and Political Opportunities**

International environmental movements try to reach their goals through all kinds of interactions with business, the general public, and, most of all, political authorities. Political opportunities refer to the specific features of a political system that help explain the different action repertoires, organizational forms, and impacts of these movements. For instance, political authorities that repress social movements provoke the application of confrontational movement strategies (demonstrations, blockades, site occupations), whereas
political elites that try to integrate challengers into the political system discourage these radical strategies in favor of a more moderate action repertoire (negotiations, participation in advisory boards, etc.). Similarly, centralized states with limited decision-making competencies for local authorities encourage the foundation of social movements and social movement organizations at the national level (e.g., France, the Netherlands), whereas decentralized states with substantial decision-making competencies at the local or regional level foster the foundation of movements at those levels (e.g., Germany, Switzerland).

The concept of “political opportunity structure” (POS) has been applied mainly to the national level to explain the differences in action repertoires, organizational forms, and impacts of social movements between different countries. International environmental movements, however, operate at the international level, interact with international political authorities, and, consequently, are confronted with international political opportunity structures. Examples of international institutions that are relevant for international environmental movements include the United Nations (the “producer” of international environmental regimes), European Union (EU-wide environmental “directives”), World Trade Organization (WTO; trade regulations with major environmental impacts), and World Bank (loans for the construction of large dams in developing countries). These institutions widely differ with respect to their formal points of access for international environmental movements and NGOs, the responsiveness of the political elites to movement demands, the homogeneity of the institution’s political elite, and, finally, the institution’s policy implementation capacity. These four dimensions of international POS can be summarized as follows:

- A formal institutional structure (open/closed)
- Informal elite strategies (integrative/exclusive)
- Configuration of power (divided elite/united elite)
- A political output structure (weak/strong)

Whereas, for instance, the formal institutional structure of the United Nations (UN) and the EU can be qualified as relatively open to social movements and social movement organizations, the World Bank and the WTO are much more closed. As predicted by POS theory, international environmental movements generally try to influence UN and EU decisions by lobbying and participating in decision-making procedures, whereas they use more radical strategies against World Bank and WTO policies. The large-scale resistance against World Bank–sponsored large dams in India and Brazil and against WTO-induced free-trade rules that are damaging for the environment are cases in point.

On the other hand, the political output structure of the World Bank and the WTO is very strong. Decisions taken by the World Bank and the WTO are almost always effectuated, a feature missing for many UN and EU decisions. For international environmental movements, it is very difficult to successfully influence World Bank and WTO policies, but, if successful, major policy changes may be the result.

Hein-Anton van der Heijden

See also Antiglobalization; Environmental Justice; Environmental Law; European Green Movements; Intergovernmental Environmental Organizations and Initiatives; International Environmental NGOs; Nongovernmental Organizations (NGOs); Sustainable Development Alternatives; United Nations Conference on Environment and Development

Further Readings

International environmental NGOs are nongovernmental organizations that, on an international and sometimes global scale, try to influence decision making by governments, corporations, and other social and political organizations, as well as by individual citizens, in order to stop or diminish environmental degradation.

International environmental NGOs can take four different forms, each with their own specific features: (1) international mass membership organizations, (2) national mass membership organizations operating at an international level, (3) international environmental think tanks, and (4) international environmental umbrella organizations. In the following sections, these four categories will be addressed one by one.

The three most important international mass membership organizations are Greenpeace, World Wide Fund for Nature (WWF), and Friends of the Earth International (FoEI).

Greenpeace

Greenpeace, founded in 1971, is a global campaigning organization with branches in 42 countries and a total constituency of more than 2.5 million. The Dutch and German branches are among its largest, each with 500,000-plus supporters, as are the British and the North American branches, each with about 250,000 supporters.

The origin of Greenpeace is in the peace rather than the environmental movement. Its very first target was the United States testing nuclear devices in Amchitka, Alaska, and nuclear weapons have been a topic of contention ever since. In 1995, Greenpeace’s ship *Rainbow Warrior* was bombed by the French army after it entered the waters of the Moruroa atoll in the South Pacific to prevent French nuclear testing.

Greenpeace has played a pivotal role in the adoption of a ban on toxic waste exports to less developed countries, a moratorium on commercial whaling, and bans on the dumping at sea of radioactive and industrial waste. Present priorities include climate change, preservation of the oceans, tropical rain forests, sustainable agriculture, and toxic chemicals. Greenpeace tries to reach its goals by lobbying, by scientific research, and, most of all, by its unconventional action repertoire. Due to its sophisticated communication strategy, Greenpeace has been very successful in raising environmental consciousness.

World Wide Fund for Nature

The WWF, founded in 1961, is the world’s largest conservation organization with a joint constituency of more than 5 million. Its largest national branches include the North American and the Dutch ones, each with about 1 million supporters. WWF started as a conservation organization with hundreds of conservation projects, mainly in southern countries, such as the restoration of orangutan habitats and the establishment of panda reserves. In the past couple of decades, it has gradually broadened its mission to stopping the degradation of the planet’s natural environment, resulting in coverage of topics such as pollution and climate change. However, contrary to Greenpeace, WWF never applies confrontational action strategies.

Friends of the Earth International

FoEI is the world’s largest grassroots environmental network, uniting 69 national member groups and some 5,000 local activist groups on almost every continent. FoEI has more than 2 million members and supporters worldwide; among its largest branches are the German, the British, and the Dutch ones. FoEI’s ideological base
members of the world wide fund for nature set up 1,600 papier-mâché pandas on October 18, 2008, to symbolize the 1,600 pandas left on Earth and to call on people to help reverse the deterioration of our natural environment. The installation was on the Parvis des Libertés et des Droits d’Homme at the Trocadéro esplanade in Paris.

Source: François Guillot/AFP/Getty Images.

could be summarized as “political ecology”: FoEI challenges the current model of economic and corporate globalization. To protect the Earth against further environmental degradation, FoEI aims to increase public participation and democratic decision making and to stimulate grassroots activism.

**National Mass Membership Organizations Operating at an International Level**

The second form that international environmental NGOs can take is the national, largely U.S.-based, mass membership organizations that have developed international programs. Groups belonging to this category include the National Wildlife Federation (5 million members and supporters), National Resources Defense Council (NRDC; 1.2 million), Sierra Club (730,000), National Audubon Society (550,000), and Environmental Defense Fund (EDF; 500,000). In sum, these five groups have a staff of well over 1,000 and a joint budget of around $200 million.

The distinctive feature of this category is its prominent role in influencing negotiations on multilateral environmental agreements. Sierra Club, Audubon Society, and Wildlife Federation are highly involved in international conservation issues such as the protection of tropical rainforests and the United Nations Biodiversity Convention. EDF and NRDC have played an effective role in the negotiations on climate change and ozone layer depletion and have also helped reshape the policies of the multilateral development banks.
Another organization belonging to this category is The Nature Conservancy, a U.S.-based conservation group with more than 1 million members and annual revenues of more than US$1 billion. The Nature Conservancy has protected more than 69,000 km² (square kilometers) in the United States and more than 473,000 km² internationally.

**International Environmental Think Tanks**

International environmental think tanks are research institutes that are loosely tied to the problem definitions and solution strategies of international environmental movements. Examples include the German Öko-Institute, the American World Watch Institute and the World Resources Institute, and the London-based International Institute for Environment and Development (IIED). IIED, founded 1971, works globally through a wide range of relationships with partners across the developing world. These partners diverge from smallholder farmers and national governments to regional NGOs and global institutions. At all these levels, IIED provides expertise in achieving sustainable development. Current priorities include the strengthening of local rights to land and natural resources, strengthening corporate responsibility for social and environmental gains, and monitoring the impact of Northern government policy.

**International Environmental Umbrella Organizations**

International umbrella organizations are “organizations of organizations,” founded to represent the interests of their member groups at a regional or global level. Examples include the European Federation for Transport and Environment and the European Environmental Bureau (EEB). The EEB, founded in 1974, is a confederation of more than 140 environmental NGOs from 31 European countries, with a combined membership of about 14 million. It is the lobbying branch of the European environmental movement at the EU level with direct access to the European Commission.

*Hein-Anton van der Heijden*

**See also** European Green Movements; Intergovernmental Environmental Organizations and Initiatives; International Environmental Movements; Sustainable Development; United Nations Environmental Summits

**Further Readings**


**INTERNATIONAL GEOGRAPHICAL UNION**

The International Geographical Union (IGU) is the international organization of academic geographers, established in 1922 in Brussels following a series of international geographical meetings, the first of which was held at Antwerp in 1871. The objectives of the IGU are to promote the study of geographical problems; to initiate and coordinate geographical research requiring international cooperation and to promote its scientific discussion and publication; to provide for the participation of geographers in the work of relevant international organizations; to facilitate the collection and diffusion of geographical data and documentation in and between all member countries; to promote meetings of the IGU, regional conferences between the international geographical congresses, and other meetings in furtherance of the objectives of the Union; to participate in any other appropriate form of international cooperation with the object of advancing the study and application of geography; and to promote
international standardization or compatibility of methods, nomenclature, and symbols employed in geography.

The IGU belongs to the International Council on Science and to the International Social Sciences Council and recognizes them as providing coordinating and representative bodies for the international organization of science and the social sciences, respectively.

IGU membership is normally by country, currently 98, rather than by individuals, national professional organizations, or national societies. Member countries are expected to establish committees for the IGU, frequently functioning through national academies of science. They promote the objectives of the Union in their respective countries, notably the international aspects. They also diffuse information from the executive committee to geographers in their country. Associate country membership applies to small or emerging geographical communities. A third membership class is of corresponding members who may be either individuals or institutions.

The IGU functions through its general assembly, consisting of all member countries and meeting every congress. The assembly elects the executive committee, which consists of the president, the immediate past president, seven other vice presidents, and a secretary-general. The president, the secretary-general, and the executive committee manage the Union’s activities, assisted by a secretariat located close to the office of the secretary-general, who serves also as the treasurer.

The working languages of the IGU are English and French. The Union holds a congress every 4 yrs. (years) and a regional conference every 2 yrs. between congresses. Locations for these meetings are competitive. The IGU maintains the Home of Geography, located within the premises of the Italian Geographical Society in Rome, which publishes a newsletter and specialized monographs. The main organ for continuous scientific work is the commissions, currently numbering 36, in addition to task forces (currently four) and special committees (currently two). The commissions reflect both veteran and novel specialties in geography. Commissions are approved by the general assembly, and they constitute a steering committee of 10 to 12 geographers from different countries and the commission itself, to which any geographers may join. Commissions hold meetings, workshops, and field trips; develop joint research projects; and publish newsletters and journals and exchange information through mailing lists.

Aharon Kellerman

See also Association of American Geographers; Institute of British Geographers

Further Readings

International Geographical Union: www.igu-net.org/uk/igu.html

INTERNATIONAL MONETARY FUND

The International Monetary Fund (IMF) is a treaty-based, voluntary association of countries based on their real or potential impacts on the world’s economy. It currently controls assets amounting to US$215 billion and has 182 member countries. Unlike the World Bank, the other “pillar” of the world economy, the IMF has no subsidiaries or affiliates. Its highest authority resides with the Board of Governors (which meets annually), each of whom is appointed by a member country.

IMF membership has varied over time, as has its role and responsibilities in world affairs. The evolution of the IMF can roughly be divided into phases based on the degree of functionality, relevance, and shifting purpose. Initially, the IMF was established at the Bretton Woods Conference (along with the World Bank) in New Hampshire with the signing of the Articles of Agreement in July 1944 and declaration of exchange values by the 44 member countries at the first meeting in 1946. However, most economists and historians disregard the impacts of the early IMF since the most important signatories (Western industrial democracies) refused to establish rules regarding the conversion of each other’s currencies into their specific reserves until December 27, 1958.
From that point until the decision by the American President Richard Nixon on August 15, 1971, to refuse conversion of U.S. notes of exchange into gold from the Federal Reserve, the IMF operated to stabilize exchange rates by setting “ pegs ” that regulated exchange values. This policy constrained the degree to which individual countries could pursue deflationary valuations to stimulate exports or foreign direct investment (FDI) but ensured that variations in exchange rates would also be constrained. In addition, it was believed that the pegs would alleviate uncertainty regarding the risks of FDI and thus help spur reconstruction following World War II. This peg arrangement reflected the desire of the Bretton-Woods signatories to incorporate both the advantages of the prewar gold standard and the flexibility of floating exchange rates that were popular during the interwar years. In addition, it was believed that the disadvantages of submission to the vagaries of the business cycle under the gold standard and the dangers of under- or overvaluation and trade imbalances under the floating exchange rate system could be avoided.

However, the IMF proved difficult to get going. It was generally acknowledged at Bretton-Woods that although the United States had emerged from World War II as the preeminent economic power, it nonetheless suffered from a shortage of currency in relation to its productive output. The U.S. contingent was accordingly wary of arrangements that would help other countries peg their currencies at values that would hurt U.S. exports. Thus, this early version of the IMF lacked effective enforcement mechanisms. This very point was hotly debated during Bretton-Woods, with the noted economist John Maynard Keynes arguing for a stronger, more credit-oriented institution that would have its own currency and accounts (essentially, a bank), while others (led by Harry Dexter White, Chief International Economist at the U.S. Treasury) pushed for IMF management of a pool of member currencies. In the end, a compromise was reached that resulted in a relatively weak version of the IMF in comparison with the current incarnation. With convertability of member currencies established in 1959, however, the IMF managed to oversee a generally sustained, long period of expanded world trade, economic growth, and stability within the industrialized democracies until 1970. With the adoption of floating exchange rates in 1973, the IMF began a 5-yr. (year) period of restructuring and adjustment that led to amendment of the constitution in 1978. The most notable adjustment was the replacement of the mechanism of pegged exchange rates with frequent consultation (usually once a year), technical advice, policy support, and loan conditions to ensure that member countries follow policies designed to support economic stability.

The IMF Today

In its current incarnation, the core mission of the IMF broadly remains the same as its founders’ intention: to ensure a smooth, orderly world economy by helping member countries find the most accurate price for their currencies. However, following the debt crises of the 1990s in Brazil, Russia, and five Asian countries (to which the IMF had extended more than US$100 billion in credit), the IMF’s expanded role of structural adjustment of economies has exacerbated or done little to forestall economic or political instability. A lack of expertise in the area of structural adjustment is unsurprising, as it was a relatively minor function of the IMF at its original inception. The enforcement mechanism was intended to prevent countries from pursuing policies detrimental to their trading partners, not to restructure economies to facilitate smooth participation in the global economy. Similar to the World Bank, the IMF can now use its power as a lender over countries struggling to honor their currency exchange values through the imposition of “ conditionalities ” that the debtor country must follow to receive a loan. These conditionalities can range from fiscal policy (curtailing domestic spending) to trade policy (increased liberalization) to monetary policy (tightly controlling reserves to discourage inflation). The logic of the conditionalities is that they are designed to ensure that the borrowing country will be able to repay the loan by stimulating exports and increasing the government’s money supply without leading to inflation. However, there are significant political costs attached to radical economic restructuring, which the IMF has been criticized for not recognizing.
Ironically, this restructuring role for the IMF would have been difficult for the architects of the system to recognize. Their focus was simply on ensuring stability within the international monetary system. Over time, the enforcement mechanism designed to ensure resolution of balance-of-payments crises (balance of payments refers to all outstanding payments and debts the residents of a country owe to other countries) and beggar-thy-neighbor monetary policies (using currency devaluation to reduce foreign debt or stimulate exports) has evolved into a restructuring tool for emerging economies. The most obvious turning point in funds development was the closure of the “gold window” by the United States; this unilateral move highlighted a fundamental limitation in the fund’s power to regulate financial matters. This power was largely ineffectual for industrialized countries that maintained large payment surpluses and was certainly impotent where the interests of the largest member of the fund, the United States, were diametrically opposed to IMF’s goals.

The current structure still reflects this imbalance in its allocation of voting power—the United States has 18% of the existing voting rights, more than double of any other country. However, calls for more democratic participation by emerging economies in the IMF have been met with some reforms. Currently, there are more than 180 member countries that receive voting rights in accordance with their level of international trade, national income, and international reserve holdings. In terms of upper-level management, however, the fund continues to reflect dominance by the founding countries. The managing director and deputy managing director rotate between a European and an American (the current director is from France, the first deputy from the United States), the IMF is headquartered in Washington, D.C., and the 24 executive directors in charge of day-to-day operations are dominated by the original signatories.

China, Russia, and Saudi Arabia also have the right to appoint one executive director each, while as a whole, the remaining member countries are allowed to nominate one director to represent all of them. Voting rights are also a function of Special Drawing Rights (SDR), which are based on national income, reserves, and trade balance. The formula applied equates one vote for every 100,000 SDR, the quotas for which are reviewed every 5 yrs. at a minimum. These quotas have increased steadily as subscription (membership) has increased over time, and if a member country does not pay its subscription, it does not receive its quota of SDR and, hence, has no voting rights. However, since the fund relies on subscriptions to finance loans and operate, countries that contribute a large share of subscriptions relative to the rest of the countries maintain a disproportionate amount of influence. This imbalance can lead to a compromise of the IMF’s core mission to maintain long-term stability in exchange rate relations as certain countries may benefit from less regulation of capital markets.

Subscriptions are not the only source of funding for the IMF, however. In addition, the IMF may borrow funds from the G-10 countries (Canada, Belgium, France, Germany, Italy, the Netherlands, Japan, Sweden, the United Kingdom, and the United States) plus Switzerland under the General Arrangements to Borrow (GAB). The GAB was used in 1998 to settle Russia’s balance-of-payments crisis. The GAB was expanded by the fund shortly afterward and currently has 17,000 million in SDR set aside for balance-of-payment crises.

The enhanced role of restructuring and policy reform during the 1980s and the resulting criticisms from that period and the notable failures during the 1990s have led to some reform. Shortly after the first round of crises, the fund reorganized the Enhanced Structural Adjustment Facility as the Poverty Reduction and Growth Facility. The new version of the facility was charged with identifying poorer countries that were able to achieve the twin goals of poverty reduction and sustainable growth. A total of 77 countries were identified as eligible for a loan in the amount of 140% of their quota payable at 0.5% interest over 10 yrs. This initiative to assist poorer countries was mirrored by the World Bank the same year with a program to aid Heavily Indebted Poor Countries (HIPC), 33 of which were in Africa, with debt relief. The condition for debt relief was that applicants must present and follow through on a yearlong strategy for reducing poverty and encouraging sustainable economic growth. Shortly after the option was developed, Uganda became the first country to apply for and receive debt relief under the Poverty Reduction and Growth Facility mechanism.
In April 2001, the IMF further expanded its surveillance functions, shifting greater emphasis toward identifying money-laundering organizations with terrorist links and pushing developing countries to exercise greater oversight of the offshore financial centers (OFC) that commonly provide money-laundering services. In 2002, a director for special operations was appointed to handle crisis response. By 2003, the fund responded to calls for more voluntary debt-restructuring methods by pushing for greater use of collective action clauses in international bond contracts. In 2006, the Monetary and Capital Markets Department was formed to strengthen fund surveillance of international finance. By 2007, roughly 90% of the fund members had agreed to increased oversight of payments, transfers, and currency arrangements.

The final arena in which the IMF has attempted reform has been its capacity to provide technical assistance. In 1993, the IMF opened regional centers in the developing and developed world to provide continuous advice from Special Missions and Resident Advisors to their respective governments on all aspects of macroeconomic issues. In addition, the IMF has maintained the IMF Institute as a training center for government officials from member nations. Postcrises, the IMF revamped the curricula of the IMF Institute to include the political impacts of the standard IMF conditionalities.

The crises of the 1990s demonstrated that the growth of international capital markets and overall connectedness of world economies by globalization eroded the extent to which floating rates insulate countries from external shocks. Nevertheless, the role of the IMF as a forum for exchange rate management continues. As of 2008, the IMF has acknowledged the need for greater focus on financial crisis prevention rather than response and has added an additional purpose of providing economic and statistical analysis on behalf of their other missions, developing financial sector Reports on the Observance and Codes (ROSC), which detail standards in the areas of transparency (for fiscal, monetary, and financial policy) at the behest of member countries wishing to improve oversight of their financial sector.

Edward Rice

See also Debt and Debt Crisis; Finance, Geography of; Globalization; Neoliberalism; Structural Adjustment; World Bank

Further Readings


regions. The complexity of this issue and the varying types of expertise required for problem solving and decision making make it relevant to various subfields of geography, for example, physical, social, economic, and political.

An international or transboundary watershed is defined as all the territory that contributes to a stream, with at least one tributary crossing a political boundary. Sixty percent of the Earth’s freshwater bodies fall within transboundary basins. Creating effective transboundary watershed management requires the establishment of working relations and sound communication between stakeholders. Especially in regions with a history of water resources management conflicts—for example, the Colorado, Nile, Tiger-Euphrates, Indus, Mekong, and Incomati Basins or those in the Middle East—the lack of explicit collaborations, communication between the responsible riparian parties, and implementation of professional conflict resolution strategies has contributed to prolonging a crisis state.

Conventions and Treaties

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes encourages riparian parties to enter into bilateral or multilateral agreements based on, for example, water quality and quantity–monitoring data exchanges. This convention is based on The Helsinki Rules on the Uses of the Waters of International Rivers, published by the International Law Association in 1966, which embraces the theory of equitable utilization and by which each riparian state in an international basin is entitled to a “reasonable and equitable share” of the watercourse and commits to not cause “substantial injury” to riparian states. The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, adopted in 1997, added to the equitable and reasonable utilization of waters clauses, such as protection of the aquatic environment and promotion of cooperative management mechanisms, and made further provisions on data and information exchange and mechanisms for conflict resolution. However, the treaty most invoked internationally for watershed protection and management is the Ramsar Convention on Wetlands (officially called The Convention on Wetlands of International Importance), which took effect on December 21, 1975, with presently 158 signatories, and addresses the protection of wetland habitats.

Establishing Effective International Watershed Management

Effective international watershed management requires comprehensive and multidisciplinary approaches and a flexible and integrative framework for addressing the biophysical, socioeconomic, and governance issues affecting water resources and their equitable distribution and use. There are several stages in the planning and management process for watersheds. Throughout the process, care must be taken that basic hydro-diplomacy principles are considered and that continued stakeholder consultation and public participation are ensured. The first step in the management process is establishing plan parameters and objectives, followed by identification of watershed components and processes (also known as a watershed physical inventory), which can be more or less detailed depending on the context. Once the basic basin characteristics and management objectives are set, the stakeholder consultation process to develop practical management options and alternatives can begin. Crucial steps in the development of a management strategy include determination of the legal and policy implications that pertain to all nations participating in the consultation process and a detailed assessment of the environmental, socioeconomic, and political impacts of the plan. While theoretically the steps leading to the top-down implementation of a viable watershed management plan are straightforward, in practice there are several limitations. These include lack of data; reduced accessibility in parts of the basin; inadequate funding; bureaucratic and administrative hurdles dictated by the different political situations of stakeholders; low levels of public awareness, information, and involvement; competing interests; and the relative lack of an international regulatory body or set of water laws pertaining to transboundary watershed management.

Alternative approaches to the top-down integrated water resources management (IWRM) strategy described above include the creation of
bottom-up institutions, through the decentralization of multigovernment services and governance to local and regional authorities, private enterprises, and communities. This approach, known as community-based water resources management (CBWRM), grew from the need to fill the gap in policy making at the regional, interstate level and implementation at the local level, since policies and management plans devised through formal interstate consultations rely on implementation at local levels. Apart from the IWRM or CBWRM strategies, other successful approaches include an adaptive watershed management approach practiced in the Columbia River Basin of the United States and an ecosystem-based river basin management approach practiced in the Ili-Balkhash Basin in Central Asia. These approaches are not mutually exclusive and, to be functional, need to sustainably integrate biophysical, socioeconomic, and political and varying levels of institutional elements in river basins. The bottom line is that transboundary management approaches must be selected on a case-by-case basis and ensure that they meet the needs of all riparian countries and, moreover, that water continues to be regarded as a nonmarketable human right and an international public good to be equitably allocated among stakeholders.

Narcisa Gabriela Pricope

See also Community-Based Natural Resource Management; Environmental Rights; Indigenous Water Management; Intergovernmental Environmental Organizations and Initiatives; Rivers; Surface Water; Watershed Management

Further Readings


INTERNET GIS

Internet GIS refers to the use of the Internet as a means to exchange geospatial data, perform geographic information system (GIS) analysis, and visualize maps. Like many other new research fields, there is no general agreement on the term Internet GIS. Several alternative names have been adopted in the GIS community to represent similar concepts, such as online GIS, distributed geographic information (DGI), and Web-based GIS (or Web GIS). These different terms are similar, but they are not synonymous. For example, Web-based GIS refers to the use of Web browsers as the primary viewers/containers to conduct GIS tasks. However, some popular GIS applications, such as Google Earth, use their own browsers instead of relying on the default Web browsers. Therefore, Google Earth is an Internet GIS application, but it is not a Web-based GIS application. The term Internet GIS has a broader and more enduring meaning than Web-based GIS. It has the capacity to include other and new applications of GIS and the Internet.

The Internet is a modern information relay system that connects hundreds of thousands of telecommunication networks and creates an “internetworking” framework. The Internet framework includes local area networks (LAN), wide area networks (WAN), Internet Service Provider (ISP) networks, wireless communication networks, and intranets. Intranets are a subset of the Internet that use the same Internet Protocol and communication technologies within a closed environment, such as a company network, but with limited access and security enhancement.

Early Internet GIS prototypes appeared in the mid 1990s. Xerox Map Viewers, the Alexandria Digital Library project, and GRASSLinks are a few representative Internet GIS prototypes from
the early period. More recently, we have wit-
nessed an explosion of interest in transforming GIS into the ubiquitous, distributed Internet GIS. These services are of value not only to various professionals using geospatial data in their daily work but also to the general public, to use spatial information for navigational and other purposes involving location-based data. There are Web sites powered by Internet GIS that allow people to check city zoning and parcel information, see where and what types of crimes are occurring in their neighborhoods, and learn when is the trash pickup day on their street.

GIS on the Internet presents a compelling and effective way of disseminating spatial information when compared with traditional paper maps or digital maps stored in centralized GIS or on CDs. Though the melding of GIS and the Internet seems a commonplace now, the idea was revolutionary in 1993. One of the earliest Internet GIS prototypes, called Xerox PARC Map Viewer, appeared on the World Wide Web that year. Developed at Xerox Corporation’s Palo Alto Research Center, the Map Viewer allowed users to zoom in on a location on a picture-based map rendering of a globe and retrieve a map of the selected area from a geographic database. In 1994, two important organizations promoting standardization in Internet GIS were established: the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO) Technical Committee 211 (TC211). Specifications developed by OGC and ISO/TC211 for spatial data formats, data exchange, and data communication have become the basis for software interoperability and the ongoing development of Internet GIS. Along with the rapid development of Internet GIS, a new term, geospatial cyberinfrastructure, is used to represent the combination of distributed high-performance geospatial computing resources, georeferenced information, geoprocessing Web services, and geographic knowledge.

**The Architecture of Internet GIS**

Most Internet GIS today adopt a three-tier architecture for system implementation (Figure 1). The first tier, called the client tier, includes the user-side Web browser and user-resident Java applets/HTML documents. The user of Internet GIS interacts with the client tier via a graphical user interface (GUI) composed usually of a map and map navigation, spatial and attribute data query, and spatial analysis tools. The primary function of the client tier is to accept users’ data requests and to...
display the results of these requests. The second tier is the middleware tier and includes the Web server and the server connector (such as Servlet connectors or Active Server Pages [ASP] connectors) to bridge the communication between clients and the map servers. The third tier is the data storage tier, which includes the map server and the spatial database server. The three-tier software architecture of Web-based GIS provides customizable functions for different mapping applications and scalable implementations for different volumes of use and, correspondingly, different hardware configurations.

### Three Types of Internet GIS

There are many different Internet GIS applications, ranging from data clearinghouses, Web mapping, data portals, Web-based decision support systems, and GPS tracking to digital Earth viewers and virtual globes. In general, we can categorize the various Internet GIS services into three types: (1) data sharing, (2) information sharing, and (3) knowledge sharing (Table 1).

Data sharing combines the functions of online data archive and data search services. Two typical applications are online data warehouses (or data archive centers) and online data clearinghouses. An online data warehouse is used for archiving, accessing, and downloading both GIS databases and/or remotely sensed imagery. A Web-based data clearinghouse can help users search and index the contents of metadata and then access the actual data through the descriptions of metadata.

The second type of Internet GIS services involves information sharing and map sharing. Multiple interactive map servers and mobile navigation services are the typical applications. Web-based mapping functions include the display, zooming in or out, and query of spatial information. The major requirement of information-sharing services is to provide effective Web-based display mechanisms and client-server communication protocol.

The third type of Internet GIS focuses on the sharing of knowledge and GIS models. This is the most challenging task for the development of Internet GIS, and only a few applications are available today. The goal is to provide online GIS modeling and spatial analysis functions without running GIS engines or software packages locally. Some Internet GIS applications use Java or other distributed component technologies (such as .NET or Web services) to develop online GIS model functions. The implementation of these Web-based software components can provide ubiquitous access for all different types of GIS applications.

### New Directions of Internet GIS

There are many Internet GIS applications using Web services and application development interfaces (APIs) for Web mapping or geocoding functions. Web services are interoperable and self-describing applications that can communicate with each other. Many software companies, such as ESRI, Google, Yahoo, and Microsoft, have developed several Web service applications and
Web Map APIs. Web application developers can use and combine these APIs and Web services into Web-based GIS applications for providing basic mapping and GIS functions. It is likely that some of today’s users of desktop GIS software packages will use in the future exclusively Web-based GIS services and that the user base of desktop GIS will shrink. The advantages of Web services include easy integration with other Web GIS applications and the low cost of software and hardware compared with the cost of software and hardware required by traditional GIS systems.

Another exciting new direction of Internet GIS is the development of three-dimensional (3D) virtual globes such as Google Earth, Microsoft Virtual Earth, and ESRI’s ArcGIS Explorer. They represent an evolution in technology, but to people outside the GIS community, it’s a revolution in the way people understand geography and the world around them. The virtual globes provide an appealing way to convey to people spatial concepts and geographic information.

Ming-Hsiang Tsou

See also Distributed Computing; GIScience; GIS Implementation; GIS Web Services; Google Earth; Neogeography

Further Readings


INTEROPERABILITY AND SPATIAL DATA STANDARDS

The International Organization for Standardization (ISO, 1993) defines interoperability as “the capacity to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.” In the context of geographic information, the functional units are geographic information systems (GIS) or Web services. The communication between these units comprises transfer of spatial data as well as querying and execution of remote services. In this respect, two types of interoperability can be distinguished: (1) syntactic interoperability refers to format of the transferred data, that is, compliance with spatial data standards, and (2) semantic interoperability builds on syntactic interoperability and refers to the accurate preservation and interpretation of the meaning of the transferred information. The focus of this entry is on syntactic interoperability and the standards enabling heterogeneous GIS and services to interoperate. Note that the kind of interoperability discussed here relies on lower-level technical interoperability, where established standards guarantee that a CD can be read in every CD drive, computers can communicate through telephone wires, electric devices can be operated on every power outlet, and so forth.

Interoperability is a key requirement for the seamless exchange of spatial data between users and organizations employing different GIS and Web services. On a broader scale, the standards enabling interoperability are the cornerstones of spatial data infrastructure (SDI). Without agreements on the formats of the transferred spatial data and the interfaces for accessing the corresponding Web services, mutual data exchange between different GIS would at least require manual transformation of the data or even be impossible altogether. The most important organizations that develop such standards for the geospatial domain are the Open Geospatial Consortium (OGC) and the ISO Technical Committee 211 (ISO/TC211), responsible for geographic information/geomatics. Both organizations have a working agreement, resulting in a frequent mutual adaptation of standards.
Data Interoperability

Before the Web became a common platform for the exchange of geodata, interoperability mainly concerned the exchange of spatial data between different desktop GIS workstations on different kinds of media. Early exchange formats for spatial information such as ESRI's shape file format were de facto standards stemming from the widespread use of their ArcGIS and ArcView software. To enter the market, other software vendors had to support these proprietary formats, which are still common today. Besides specialized GIS formats, vector data were often exchanged in file formats originally developed for computer-aided design (CAD) software. Raster data were (and still are) mostly exchanged in standard graphics file formats such as JPEG, PNG, or (georeferenced) TIFF.

In a more contemporary sense, interoperability is usually reached by standards that are established by industrial consortia or independent standardization organizations. One such vendor-neutral standard for geographic features that is commonly used today is the Geography Markup Language (GML) introduced by the OGC. GML is an eXtensible Markup Language (XML) encoding for the transport and storage of geodata that can be tailored to specific applications via application schemas. Application schemas define the specific feature types and property types that are relevant for a given domain based on the GML meta schema. Due to the complexity of GML caused by this multipurpose design, numerous developers favored the simpler Keyhole Markup Language (KML), especially for nonprofessional or Web 2.0 mash-ups. KML was originally a proprietary format used in Google Earth and has been put under control of the OGC in 2007. It became an open OGC standard in 2008.

Besides the actual data, their descriptions in metadata must also be standardized to allow interoperable data discovery in catalog services. This standardization refers to the metadata encoding as well as the minimum set of mandatory properties, allowing for metadata profiles for different applications. The ISO 19115 specification (part of the ISO 191xx set of standards for geographic information) provides such a standard specifically developed for metadata on geodata. It comprises more than 400 different elements, of which a small subset is compulsory. Besides ISO 19115, the Dublin core metadata standard is also commonly used for spatial information, although it is a general-purpose standard and has not been developed specifically for geodata.

Web Service Interoperability

Web services enable loosely coupled service-oriented architectures that provide Internet-based access to spatial data stored in remote databases. They allow for the execution of distributed geoprocessing functionality such as the online computation of standard GIS operations. In addition to standards for the formatting of the transferred data, Web services require standardized interfaces for communication with these services. The OGC has developed a number of standards for geospatial Web services, with the most widely adapted being the Web Map Service (WMS) and Web Feature Service (WFS) specifications for the retrieval of raster and vector data, respectively. Further specifications cover advanced functionality such as geodata processing (WPS), sensor observation (SOS), or location services (OpenLS; see Percivall, 2003, for a complete overview). OGC specifications define Web service interfaces by specifying the formats for requests and responses. This implementation-independent approach allows existing proprietary Web services to be subsequently equipped with an additional OGC compliant interface. Such a mapping is especially important for the integration of existing services into SDIs and follows an approach that has proven useful on the technical level: For a user, it is sufficient to know the interface, such as a power outlet or a WMS interface, and the corresponding interactions. It is then irrelevant how the electric power is generated or how a map tile is composed to make use of the interface. At the same time, this approach allows developers great latitude in the actual implementation of the services.

See also GIS Web Services; Metadata; Open Geodata Standards; Open Geospatial Consortium (OGC); Semantic Interoperability; Spatial Data Infrastructures
Interviewing is one of the most common social science research methods; it is used by a wide array of human geographers to gather information about people and particularly their views about their world and how they feel they and others fit within it. Interview “data” are typically obtained through verbal communication between the researcher and participant: face-to-face, over the telephone, and, occasionally yet increasingly, over the Internet as textual chat or Voice Over Internet Protocol (VoIP). The term interview is used to describe a wide range of techniques in both popular culture and academia. Though it is sometimes used to describe face-to-face, closed-ended, survey questionnaires that are filled out by the researcher, interview more commonly describes the far less structured qualitative technique.

The interview as a modern-day qualitative social science method developed alongside participant observation and other so-called field methods, particularly within the Chicago School of Sociology and their now-famous urban ethnographies of the 1920s, 1930s, and beyond. Among the prominent influences at this time were the work of George Herbert Mead and the philosophy of pragmatism. Both were later interpreted by Herbert Blumer, who coined the term symbolic interactionism in an attempt to simplify the philosophical underpinnings of the interview method. The emphasis of symbolic interactionism is that it is mainly through interaction between humans that social meaning and action can be fully understood. This approach is consistent with the works of several German philosophers and the philosophy of phenomenology, which predates the Chicago School. Phenomenology in particular was opposed to the strict requirements of objectivity in highly structured positivist social science. Yet phenomenology also forms the philosophical basis for reflection, or reflexivity, as a central aspect of qualitative interviewing. The interviewer is expected not only to reflect on the conscious intentions of the research participants but also on his or her own intentions as well as the influence of his or her social position within the interview process.

In terms of practical advantage over more structured methods, qualitative interviews are used in three interrelated types of research: (1) topics that have not yet been studied extensively; (2) exploratory research with groups of people who are hard to reach, such as the homeless; and (3) studies that seek to understand personal or sensitive topics or that require participant reflection. In the case of new topics, and by virtue of the flexible nature of interviews, they provide the opportunity to develop new theoretical concepts rather than simply test existing ones. In relation to the latter two types of research, because the interview is more personable than questionnaires, interviews ideally allow the researcher and the participant to develop a positive rapport or social trust. This helps get at the deeper meanings that such research requires.

Qualitative interviewing is meant to be more conversational than questionnaire-based survey interviewing. Qualitative interviewing involves the concept of the researcher as instrument, whereby the researcher, as a social-interpretive being, is considered very central to the interview and interpretive processes. Thus, the researcher’s ability to react to the social situations within the interview is not nearly as constricted in the name of objectivity as it would be in the case of survey questionnaires. That said, the researcher often withholds at least some of his or her own personal views—a source of some debate among interview practitioners.

Further Readings
ISO/TC 211 Geographical Information/Geomatics: www.isotc211.org
It is the subjective meanings of the participants that are the focus of the qualitative interview, and somewhat paradoxically, these meanings themselves are at least partially socially constructed by the interview process itself. That is, interviews do not entirely tap into preexisting understandings; the interview conversation helps articulate some meanings that might otherwise be left veiled by the participant’s need to get on with daily life. By responding to participants in ways that more closely approximate everyday social life, the qualitative interviewer can be more empathetic, which ideally contributes to a positive rapport. Furthermore, the researcher as instrument can simultaneously interview and observe such that the interview process is conducted holistically. Thus, the presentation of self is important in the interview since interview participants do indeed act in response to how the researcher presents himself or herself—for example, as an academic, student, activist, feminist, Muslim, wealthy, or politically left of center. In the case of face-to-face interviews, the researcher as instrument also entails attention to the physical presentation of self in terms of dress, mannerisms, and even the setup of the interview location since these all can both enable and constrain what may be learned through interviewing.

All types of qualitative interviews are meant to be conversational but vary along a continuum from structured to unstructured. Interviews typically involve a list of topics to be covered—an interview guide or interview schedule. For example, semistructured interviews may involve a detailed list of topics and probes in the guide; yet the researcher may nevertheless retain the flexibility to cover the topics out of order or pursue topics raised by the participant. Not only does this allow the interview to be more conversational, it surrenders some control over the path of the conversation to the participant.

Interview “data” are commonly interpreted as text, though the interview itself is often audio recorded and subsequently transcribed into text. Otherwise, field notes taken during the interview are the substance of interpretation. The choice or recording strategy may thus involve trade-offs between the intrusiveness of the recording method, accuracy, and the comfort level of the participant. In all cases of data recording, reflections on the interview situation (e.g., reasons for guarded responses) are recorded during or soon after the actual conversation. Thus, interpretation occurs throughout the interview process from topic inception through write-up.

Despite the researcher’s desire to share power over the form and content of the conversation, interviews, like other qualitative methods, involve some serious ethical challenges. This goes beyond the more straightforward issue of obtaining informed consent, which allows participants to withdraw from the research without negative impacts. However, since much interview work is conducted with disadvantaged groups in society, there are more subtle ethical considerations over issues of power, control, and the uses to which data are put. In most instances, the researcher has the most control over the content and ultimate trajectory of interviews and particularly what is interpreted from them. This can create tensions between interpretations that are intended for more academic audiences and those that serve to more directly address the problems of the group(s) being studied. Such issues are most keenly debated among feminist and participatory action researchers and between them and other types of less action-oriented interview practitioners.

Jamie Baxter

See also Chicago School; Fieldwork in Human Geography; Feminist Methodologies; Participant Observation; Phenomenology; Positionality; Qualitative Methods; Situated Knowledge

Further Readings


Invasion and succession are the establishment of one or more species in an area previously uninhabited by those species and the subsequent progression of the ecological community’s species composition in that area through time. As ecological terms, *invasion* and *succession* are usually discussed independently from each other. Invasion, in an ecological sense, occurs when a species, usually an exotic or nonindigenous species, is introduced to an area and is able to persist in that area, often at the expense of native species. Ecological succession refers to the changes in species composition in an area over time. Succession is typically conceptualized as a progression of species compositions in an area that eventually achieves a climax stage, which remains dominant in an area until a disturbance in that area (e.g., a fire or a strong storm) resets the species composition to an earlier stage of succession. This is an example of secondary succession. Primary succession occurs when ecological communities form in an area that had no previous communities or abiotic habitat development. Ecological community development on land just formed by a volcano or newly uncovered by a landslide is an example of primary succession.

The invasion of an ecological community by an exotic species is typically viewed as a negative process. The invading species can potentially disrupt the interspecies ecological dynamics of the native community. This can result in the loss of native species in an area. The lack of natural predators of the invading species can result in their unchecked population growth. If the invading species are pathogenic to the native species, the natural defenses of the native species may not be able to resist the invading species. These factors can result in catastrophic ecological disruptions to native communities.

Combining the ecological processes of invasion and succession provides an integrative view of the changes that ecological communities experience through time. This has become more important as modern economic globalization continues to expand linkages between different places in the world. These links are often in the form of major physical transportation agents, such as boats, airplanes, and trains, which have transported many species to areas beyond their native ranges. The introduction of these species to new areas provides them with invasion opportunities. Once these invasive species become established in an area, they will compete with native species for niche space within the stages of succession that the area experiences. Successful invasive species eventually find a stable niche within a native community and in time are described as nonnative elements of the community.

Matthew Miller

See also Biogeography; Biota and Climate; Biota and Soils; Biota and Topography; Biota Migration and Dispersal; Ecological Zones; Ecosystems; Ecotone; Exotic Species; Human-Induced Invasion of Species; Species-Area Relationship

Further Readings


Walter Isard is the father of the discipline of Regional science. Often characterized as an “economic geographer,” his work is much broader, also encompassing urban and regional planning, operations research, transportation, applied engineering, political science, sociology, and ecology.
The focus of regional science is on space and location, and it treats a region (any subnational entity not necessarily defined by political boundaries) as an organic whole.

Walter Isard was born in Philadelphia in 1919. He graduated from Temple University with honors in 1939 and then studied at Harvard and the University of Chicago. While working for the National Resource Planning Board during World War II, he completed his dissertation on building cycles and transportation development and received his PhD from Harvard in 1945. Isard returned to Harvard that year as a research associate and an instructor, and he designed the first course in location theory there. By the late 1940s, he helped form a small group of economists, which eventually expanded in number and breadth to include people from related disciplines, culminating in the founding of the Regional Science Association in 1954. Isard moved to the department of city and regional planning at Massachusetts Institute of Technology in 1953. In 1956, he was invited to join the economics department at the University of Pennsylvania but insisted on forming his own department of regional science, which he served as chair until 1975. He initiated the Journal of Regional Science in 1958 and later founded the journals Regional Science and Urban Economics and The International Regional Science Review in the early 1970s.

The second discipline founded by Isard was Peace Science, a rigorous, interdisciplinary inquiry into the topic. In 1963, he helped form what is now the Peace Science Society, and in 2006, he established the journal Peace Economics, Peace Science and Public Policy.

Isard’s key initial contribution was the reformulation of the work of European location theorists, such as von Thünen, Alfred Weber, Walter Christaller, and August Lösch, into neoclassical microeconomics. Although there were several scholars who worked on this topic in the United States previously, Isard’s Location and Space Economy provided a comprehensive, unified framework. Prior to this, economics lacked a formal spatial dimension and treated the economy as if it operated on the head of a pin. Interestingly, the neoclassical core of regional science has caused a distancing between this discipline and human geography, as the latter places an increased emphasis on social theory and political economy.

Isard published several other influential books over the next 20 years, including Industrial Complex Analysis and Regional Development in 1959 (an early foray into agglomeration economies); Methods of Regional Analysis in 1960 (instruction on a broad spectrum of analytical and practical tools, including input-output analysis and various types of mathematical programming); General Theory: Social, Political, Economic and Regional in 1963 (to further unify various aspects of spatial analysis, economics, and related disciplines); Ecological Economic Analysis for Regional Development in 1972 (a precursor of modern ecological economics); and the textbook Introduction to Regional Science in 1972.

In 1977, Isard moved to Cornell University, where he was given appointments in the department of economics and city and regional planning, as well as the regional science program and peace science program, which he established (he had held a visiting appointment at Cornell since 1971). Isard is now professor emeritus at Cornell and remains active in several fields at the time of this writing.

Isard was the mentor of many notable scholars at the University of Pennsylvania, including William Alonso, Eugene Solensky, and David Boyce. His students in economics at Cornell included Luc Anselin and this author. He has been listed among the ranks of leading economists, and his contributions to other disciplines, especially geography, are well acknowledged.

Adam Rose

See also Input-Output Models; Location Theory; Models and Modeling; Regional Science; Regional Science Association International (RSAI)

Further Readings

ISLAND BIOGEOGRAPHY

Islands have always had a great influence on the natural sciences, far out of proportion to the tiny fraction of Earth’s surface that they cover. The reason for this is straightforward: Islands and other insular habitats, such as lakes, caves, springs, and mountaintops replicate natural experiments. Island biogeography is a field within biogeography that attempts to describe and understand the innumerable patterns in the distribution of species arising from these natural experiments.

**Island Types**

Islands can be divided into two broad types: (1) true islands, land wholly surrounded by water, and (2) habitat islands, other forms of insular habitat, that is, discrete patches of habitat surrounded by strongly contrasting (hostile) habitats.

In terms of geology, geography, and biology, true islands can be subdivided into two types:

**Oceanic Islands.** These are islands formed over oceanic plates; they are of volcanic origin (although sometimes their subaerial parts are in part or wholly composed of sedimentary, and especially coral, formation as the volcanic core has sunk) and have never been connected to continental landmasses, from which they are separated by deep sea (e.g., Azores, Canaries, Hawaii, Iceland, Tristan da Cunha). They generally lack indigenous land mammals and amphibians but typically have a fair number of bird species and insects and usually some reptiles.

**Continental Islands.** These islands are located on the continental shelf. Typically, many of these islands have been connected to the mainland during the Quaternary ice ages (e.g., Britain, New Guinea, Sri Lanka, Sumatra, Trinidad). They are rarely remote and always contain some land mammals and amphibians, as well as representatives of the other classes and orders in considerable variety.

**Continental Fragments.** These are islands that formed on ancient fragments of continental rock stranded out in the oceans by plate tectonic processes, although by their location they might otherwise pass for oceanic islands (e.g., Crete, Cuba, Madagascar, New Zealand, Seychelles). Typically, they exhibit high endemism and relictualism.

**The Significance of Islands**

The biotas of islands, especially of oceanic islands, characteristically differ from continental biotas in four main ways: They are relatively impoverished, unsaturated, and disharmonic, and they harbor a disproportionally high number of endemic species. Considering New Guinea as the largest island, islands constitute only 3% of the total landmass of the Earth, while more than 15% of plant, land snail, and bird species are restricted to islands. In the case of higher plants, more than 13% of the world’s species are endemic to just 13 islands/archipelagoes. The high endemism of islands means that island species are crucially important to global biodiversity. The first three traits mentioned above are often considered as being largely responsible for island species and communities being particularly fragile when exposed to external pressures.

The ecosystems of islands (coastal, marine, and inland) provide valuable services to more than 500 million people—namely, food, tools, industry, medicine, transport, and waste disposal. With increasing human population pressures through high migration and reproductive rates, island systems face several serious issues both in the immediate and in the near future. The natural land cover of island systems has changed drastically under the pressure of growing human populations and the consequent exploitation of the landmass (e.g., the Azores have lost more than 90% of their original native forest during the five centuries of human occupation). On some islands, the impact has exceeded critical thresholds, particularly along the coastal periphery. Anthropogenic changes range from deforestation for cropland to urbanization and the abandonment of degraded land. All these have immediate repercussions in destruction of the remaining habitat and loss of biodiversity.

In the current age of mass anthropogenic extinctions, islands qualify as “hot spots,” combining the attributes of high levels of unique biodiversity, recent species extinctions, and likely future species losses (i.e., they have a high unpaid extinction debt). A disproportionate fraction of all endangered and recently extinct species are island species. The majority of recorded species extinctions since circa AD 1600 have occurred on islands.
Approximately 70% of recorded extinctions in five animal groups (mammals, birds, amphibians, reptiles, and land snails) have been island species. Avian extinctions are overwhelmingly concentrated on oceanic islands, especially on Hawaii and New Zealand, with very few elsewhere. With few exceptions, oceanic island avifaunas have lost a significant proportion of their endemic species over the past 1,000 years.

### Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Islands</th>
<th>Continents</th>
<th>Oceans</th>
<th>Total</th>
<th>% Insular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
<td>51</td>
<td>30</td>
<td>4</td>
<td>85</td>
<td>60</td>
</tr>
<tr>
<td>Birds</td>
<td>92</td>
<td>21</td>
<td>0</td>
<td>113</td>
<td>81</td>
</tr>
<tr>
<td>Reptiles</td>
<td>20</td>
<td>1</td>
<td>0</td>
<td>21</td>
<td>95</td>
</tr>
<tr>
<td>Molluscs</td>
<td>151</td>
<td>40</td>
<td>0</td>
<td>191</td>
<td>79</td>
</tr>
<tr>
<td>Insects</td>
<td>51</td>
<td>10</td>
<td>0</td>
<td>61</td>
<td>84</td>
</tr>
<tr>
<td>Plants</td>
<td>139</td>
<td>245</td>
<td>0</td>
<td>384</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>504</td>
<td>347</td>
<td>4</td>
<td>855</td>
<td>59</td>
</tr>
</tbody>
</table>

(Table 1). Approximately 70% of recorded extinctions in five animal groups (mammals, birds, amphibians, reptiles, and land snails) have been island species. Avian extinctions are overwhelmingly concentrated on oceanic islands, especially on Hawaii and New Zealand, with very few elsewhere. With few exceptions, oceanic island avifaunas have lost a significant proportion of their endemic species over the past 1,000 years.

Islands provide replicated series of more or less self-contained systems that can serve as nature’s “laboratories.” They have thus featured predominantly in the development and testing of theories. The equilibrium theory of island biogeography (ETIB) is arguably the single most influential theory in the study of geographic patterns of diversity. Its influence is marked not just by the research it has motivated but also by the theories and applications it has spawned/influenced (e.g., species-energy theory, metapopulation theory, island assembly theory, neutral theory, and stochastic niche theory).

The dynamic, equilibrium model of ETIB postulates that the number of species of a given taxon found on an island will be the product of opposing forces leading consecutively to the gain and loss of species and resulting in a continual turnover of the species present on each island through time. This is captured in graphical mode in Figure 1: The immigration rate declines exponentially and the extinction rate rises exponentially as an initially empty island fills up toward its equilibrial richness value (shown by the intersection). The immigration rate curve flattens with increasing isolation, and the extinction rate with increasing area, thereby generating a family of curves providing unique combinations of richness and turnover for each combination of area and isolation.

Although ETIB has proved more difficult to test than first hoped, as a heuristic device it has been and continues to be extremely important in organizing thought on patterns of species diversity and in providing a framework against which to consider other models of diversity. Modifications and improvements on the basic ETIB model can help provide a more robust framework for evaluating and predicting patterns of species diversity, although some contend that sharper departures from this theoretical framework are needed.

One key element in any general model is to more explicitly recognize the important role that adaptive radiation plays in increasing species diversity on islands. This is mentioned but not fully developed in the ETIB. Recently, it has been proposed that for oceanic islands, it is important to consider island “ontogeny,” that is, the life history of an island itself, for describing the interplay of immigration, extinction, and speciation in establishing species richness. A volcanic island’s size, topographic complexity, ability to support life, and potentially its likelihood of promoting speciation change over geological time as the island forms out of the ocean, grows larger and higher, and then begins to shrink, lose elevation, and eventually become eroded below the surface.
of the sea (Figure 2). This and other contributions can offer the foundation for an expanded theory of island biogeography, unifying ecological and evolutionary biogeography.

**Figure 1** The equilibrium model of island biogeography


**Notes:** An equilibrium number of species (S) is set by two opposing processes: immigration (I) and extinction (E). The rate of immigration decreases and the rate of extinction increases with increasing richness; the rate of immigration reaches zero when the entire pool (P) of potentially immigrating species have arrived. Immigration rates on islands far (I far) from the source pool are expected to be lower than those on near (I near) islands. Extinction rates are expected to be higher on small (E small) islands than on large (E large) islands. Hence, different equilibrium numbers of species are established based on the area and the isolation of the islands (SF,S; SF,L; SN,S; SN,L). Differences in rates of species turnover (T) are expected to vary with the combination of immigration and extinction rates that characterize any given island (TF,L; TF,S).

Within a few years of the publication of the ETIB, its application to the field of conservation biology was being vigorously debated. This was based on the realization that reserves and national parks formed islands, that is, habitat islands, inside human-altered landscapes (habitat fragmentation), and that these reserves could lose species as they “relaxed toward equilibrium,” achieving a new lower equilibrium number.

Based mainly on island biogeography theory, a theoretical framework for fragmentation research has been established, seeking to derive
key reserve network design principles (Figure 3). One of the most prominent contributions was the so-called SLOSS debate, which posed the question “Given the opportunity to put a fixed percentage of land into conservation use, is it better to opt for a single large or several small reserves?” Unfortunately, the ETIB does not tell us with any precision how species should be distributed across a system of fragments, and this is crucial to the issue of whether it is better to advocate one very large reserve or several smaller ones of the same total area.

In general, island theory provides a basic conceptual model for understanding habitat fragmentation. However, apart from a number of broad generalizations, the relevance of island theory for understanding fragmented ecosystems has proved to be limited, so far. Recently, a new subdiscipline has emerged, conservation biogeography, which is the “application of biogeographical principles,
### Figure 3  Design guidelines for reserves as suggested by the theory of island biogeography

<table>
<thead>
<tr>
<th>Worse</th>
<th>Better</th>
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<tbody>
<tr>
<td>a)</td>
<td></td>
</tr>
<tr>
<td>Small reserve</td>
<td>Large reserve</td>
</tr>
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<td>b)</td>
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<td>Fragmented reserve</td>
<td>Unfragmental reserve</td>
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<td>c)</td>
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<td>Higher edge effects</td>
<td>Lower edge effects</td>
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<td>d)</td>
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<td>Isolated reserves</td>
<td>Increased connectivity (corridors)</td>
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<td>e)</td>
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<tr>
<td>Isolated reserves</td>
<td>Increased connectivity (stepping stones)</td>
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<td>f)</td>
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<tr>
<td>Partial protection</td>
<td>Complete protection</td>
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<td>g)</td>
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<td>Uniform habitat</td>
<td>Increased habitat diversity</td>
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<td>h)</td>
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<tr>
<td>Local perspective</td>
<td>Regional perspective</td>
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<td>i)</td>
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<tr>
<td>Humans excluded</td>
<td>Human integration (buffer zones)</td>
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</table>

theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity.” Within the context of conservation biogeography, we can reevaluate the theoretical frameworks provided by island theory, their relevance to particular systems, and their wider and important role in helping us understand the sorts of effects that might be operative in real-world contexts.

Kostas A. Triantis and Robert J. Whittaker

See also Atoll; Barrier Islands; Biodiversity; Biogeography; Bioregionalism; Biosphere Reserves; Biota Migration and Dispersal; Coral Reef; Diamond, Jared; Extinctions; Human-Induced Invasion of Species; Islands, Small; Single Large or Several Small (SLOSS) Debate

Further Readings


ISLANDS, SMALL

While one can envision at a global scale that all land is an island between the Earth’s vast oceans and seas, relatively small islands dot much of the globe, many of which can easily be traversed by foot in only a few hours. An accurate count of small islands is difficult, as the number changes with tidal conditions and minimum-size requirements. Most are so tiny as to be uninhabited, and a high percentage of them have been termed internationally by organizations such as the United Nations as small-island developing states (SIDS) since 1994. However, there is no formally recognized definition of “small islands.” Approximately, 50 SIDS are located across the Pacific, Atlantic, and Indian Oceans. Small islands tend to be more environmentally fragile, insular, and remote than large islands (e.g., Madagascar, Borneo, New Guinea, or even Greenland) and thus deserve their own entry.

Small islands may be divided into high islands and low islands, and are important to geography for many reasons. For example, there are unique physical processes that form high and low islands: Biodiversity, and endemism in particular, is remarkably high on them. Small islands are likely to be early victims of climate change as reefs bleach, sea-level rises, and storms intensify, which, given their tiny carbon footprint, makes their condition an environmental justice issue. Of course, their relative remoteness results in great social and marine and terrestrial biophysical data gaps, and this too should interest geographers.

High Islands

One approach to classifying small islands is based on their formation. High islands such as the Hawaiian Islands, Bora Bora, and Pohnpei are created by volcanic action, often through tectonic plates moving over fixed hot spots of pressurized magma in the upper mantle. This often results in a dominant conical form with basaltic geology and high relief (see high island photo).

High-island topography causes orographic lifting of moisture-laden clouds fed by the surrounding ocean, producing remarkable amounts
of rainfall. Some of the wettest places on Earth are found on small high islands (e.g., approximately 1,200 millimeters per year on Kauai in Hawaii). This high-island relief, together with being spread about large spaces and in great isolation, also results in a tremendous degree of habitat diversity. In the tropical small islands, streams, terrestrial forests, mangrove forests, grasslands, and fringing coral reefs produce habitat for a large number of endangered or endemic species. Charles Darwin’s theory of evolution and E. O. Wilson’s theory of island biogeography are two scientific cornerstones relating to understanding island biodiversity.

Taking the Micronesia region of the Pacific Ocean as an example, which includes the Republic of the Marshall Islands, Territory of Guam, Commonwealth of the Northern Mariana Islands, Republic of Palau, and Federated States of Micronesia (FSM), all the nations have taken the “Micronesia Challenge” (MC), a commitment to biodiversity conservation, launched in Curitiba, Brazil, in 2006, during the eighth meeting of the Conference of the Parties to the Convention on Biological Diversity. The jurisdictions involved in the MC have committed at least 30% of their marine areas and 20% of their terrestrial areas to be under effective management by 2020. It is estimated that 30% of the world’s coral reefs are significantly damaged and the extent of the damage will double by the year 2030 if no conservation measures are undertaken. Notably, approximately half of the world’s plant and animal species that have become extinct are island species. The jurisdictional area associated with the MC represents 10% of the Pacific Ocean, and when implemented, the MC will protect 10% of the world’s reef area and 462 coral species, which represent 58% of all known corals. The then-FSM vice-president, Killion, described the initiative as a regional framework that is aimed at poised the Micronesian island governments toward achieving the targets and objectives set forth in the Convention on Biological Diversity and the Millennium Development Goals. Micronesia is a biodiversity “hot spot.”

Low Islands and Atoll Structures

In contrast to high islands, low islands are created by deposition of coral rubble and sand on shallow reefs. These shallow reefs form when volcanic islands sink, either through subsidence of the tectonic plate as it moves toward subduction or through compaction as the underlying rocks cool and shrink. As the volcanic cores sink below
the ocean surface, coral reefs grow upward, maintaining a relatively constant position relative to the surface. Eventually, the volcanic core is completely buried in coral growth, and an atoll, a roughly circular collection of islets around a shallow lagoon, forms. The size of each islet is typically less than 5 square kilometers, with maximum elevation less than 5 meters. Soils are nearly entirely composed of coral sand, with a very shallow freshwater lens. Figure 1 shows Chuuk Lagoon, the world’s largest “almost atoll”—note the high islands in the middle and the remaining low islands. Note in the low islands photograph the development of major islands in corners and the protection from wave action the reef provides for the interior of the lagoon, making fishing and other activities safer. Freshwater lenses tend to be thicker on the inside of the structure.

Saltwater intrusion poses challenges for both vegetation and human settlement on low islands. Low islands produce limited habitat and species diversity. There are few perennial (or even ephemeral) streams; vegetation is predominately herbaceous strand or strand forest; and though mangroves are possible, they are not nearly as developed as on high islands. Climatic diversity is assumed to be nonexistent on atolls because of the relative lack of topographic variation on low islands. Low islands

Figure 1  Chuuk Lagoon from satellite imagery, Chuuk State, Federated States of Micronesia

Source: Created by Dr. William James Smith Jr. from LSat.

Note: Coral appears in light blue.
also typically have smaller populations. Given the projections for climate change, low islands may serve as the “canary in the coalmine” for global climate change. Islands need not be covered permanently with water to be uninhabitable, as unsafe or saline conditions from washover and sea-level rise may make inhabiting such islands impossible. This will create a loss of cultural as well as biophysical diversity, which is unfortunate given that small-island populations are not industrialized and produce negligible greenhouse gases, while their vegetation and large national marine areas serve as significant global carbon sinks.

William James Smith Jr. and Reed Perkins

See also Archipelago; Atoll; Barrier Islands; Biodiversity; Climate Change; Coral Reef; Coral Reef Geomorphology; Island Biogeography

Further Readings


Isopleth maps are a type of thematic map used to display and model observations of phenomena with a continuous distribution by representing the values as a third-dimensional surface draped over the area. This common mapping technique is appropriate for diverse topics. Similar terms, mapping techniques, value interpretation, and specific isopleths, especially contours, are discussed.

Broadly called isoline maps, a distinction is sometimes made between isometric and isoplethic mapping, wherein isometric maps display real values such as rainfall amounts and isoplethic maps display calculated values such as population density. The terms *isarithm* and *isogram* are generally synonymous. *Iso* means “equal,” and *pleth* refers to “quantity.”

If something can be measured or generalized at any location, such as air temperature, then potentially, isopleth mapping can be used to show the spatial patterns. Observations cannot be made everywhere, so isopleth maps are constructed by interpolation from measurements at specified locations or associated calculations.

Isopleth maps use lines of equal value to portray patterns. These isopleths or isolines are plotted by assuming an even rate of change between the locations of known values. An isopleth interval identifies the difference in value between adjacent isopleths. The lines drawn are multiples of this isopleth interval. Smaller intervals mean more lines will be shown and more detail will be interpolated. This does not enhance accuracy. Isopleths enclose areas of either higher or lower values. They can neither cross nor split apart, because the line can have only one value. More closely spaced isopleths indicate more rapidly changing values.

Isopleth maps are read by identifying the value of the line through the point or the value of the adjacent higher and lower lines. For a point not on a line, a range is indicated. A value can be interpolated from the relative location between the lines, but the reader should remember the original generalization process used to produce the maps and not infer excessive detail.

The most difficult aspect of reading isopleths involves identifying the continuity between the high and low centers. A low center or a depression is an area completely surrounded by higher values. The primary skill involves maintaining the value trend. Any reverse in the trend is indicated by a repeated line value. If the value of the lines is increasing in the direction of a high center and a low center is encountered, the line value most recently passed will be repeated, indicating the change in the trend. However, if the trend is going down from a high center into a depression, the values do not repeat (Figure 1). Shaded isoline maps color the areas between the lines for clarification.

A contour map shows elevation of the land surface and is a specialized isopleth map. These differ by the inclusion of hachures, small tic marks pointing downslope, added to the lines in the low centers. The same interpretation skills are applied to read the values. The first hachured contour line has the same value as the lower adjacent unhachured line.

**Figure 1** Continuity of values on isopleth maps

Source: Author.
Specialized names are applied for different data. Lines that connect points of equal temperature are isotherms, and isobars are lines that show equal atmospheric or barometric pressure (Table 1). The diversity of line types demonstrates the versatility and usefulness of isopleth mapping.

Miriam Helen Hill

See also Cartography; Choropleth Maps; Dasymetric Maps; Map Generalization; Map Visualization

<table>
<thead>
<tr>
<th>Name for Isoline</th>
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<tbody>
<tr>
<td>Geoisotherm</td>
<td>Underground temperatures</td>
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<tr>
<td>Isallobars</td>
<td>Changes in air pressure through time</td>
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<td>Isobar</td>
<td>Barometric or atmospheric pressures</td>
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<tr>
<td>Isobaths</td>
<td>Water depths</td>
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<td>Isobathytherm</td>
<td>Water depths with equal temperatures</td>
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<td>Isobrunt</td>
<td>Occurrences of thunderstorms</td>
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<td>Isoceraunic</td>
<td>Numbers of thunderstorms</td>
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<td>Isochalaz</td>
<td>Frequencies of hail storms</td>
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<td>Aurora recurrences</td>
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<td>Production costs</td>
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<td>Cloud cover</td>
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<td>Thicknesses of stratigraphic unit or group</td>
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<td>Times of flowering plants</td>
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<td>Brightness or illumination</td>
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<td>Plankton or plankton species</td>
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<td>Vertical wind shear strength</td>
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<td>Temperatures</td>
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<td>Isotim</td>
<td>Transportation costs from raw material source</td>
</tr>
</tbody>
</table>

Table 1  Names of selected isolines

Source: Author.

Further Readings

