Geographic Concepts

Industrial Revolution
location theory
variable costs
friction of distance
distance decay
least cost theory
agglomeration
deglomeration
locational interdependence
primary industrial regions
break-of-bulk point
Fordist
post-Fordist
just-in-time delivery
global division of labor
intermodal connections
deindustrialization
outsourced
offshore
Sunbelt
Technopole

Learn More Online

About the port of Rotterdam:
http://www.portofrotterdam.com

About Nike
http://www.nikebiz.com/company_overview/

Watch It Online

About Wal-Mart's influence on Bentonville, Arkansas
http://www.pbs.org/wgbh/pages/frontline/shows/walmart/

CHAPTER 13

Human Environment

Field Note Disaster along Indian Ocean Shores

Figure 13.1
Galle, Sri Lanka. The December 26, 2004 Indian Ocean Tsunami destroyed this passenger train in Sri Lanka, ripping apart tracks and killing more than a thousand people. ©AP/Wide World Photos.

Watching the horrors of the tsunami of December 26, 2004 unfold on screen (Fig. 13.1), I found it quite eerie to see such devastation in places where earlier I walked and drove and rode—like that Sri Lankan train on which I took a group of students in 1978 including my own children—now smashed by the waves, the carriages toppled, killing more than a thousand passengers, some of them tourists. And the beaches near Phuket in Thailand, so serene and beautiful in memory, now proved a fatal attraction leading to disaster for thousands more, tourists and workers alike.

I went online to follow the events of that day and those that followed, horrified by the rising death toll and by the images of destruction and devastation. The in-box of my e-mail began to include messages from former students who remembered my in-field assessment of the tsunami risks in Southeast Asia. But I had not been especially prescient. Just like people farming the fertile soils on the slopes of an active volcano, people living at or near sea level near an earthquake zone live with risk.

A few weeks later I began to hear and read stories about an English girl named Tilly Smith, who had been vacationing with her parents at a hotel on the beach at Phuket and was on Maikhao Beach when she saw the water suddenly recede into the distance. Tilly had just taken a geography class in her school not far from London, and her teacher, Mr. Andrew Kearney, had told the class what happens when a tsunami strikes: the huge approaching wave first sucks the water off the beaches and then the sea foams, rises and returns as a massive, breaking wall that crashes over and inundates the whole shoreline. Tilly saw what was happening and alerted her parents, her father told hotel security, and they ran back and forth, screaming at beachgoers to seek shelter on higher ground in the hotel behind them. About a hundred people followed the Smith family into the building, and they all survived. Of those who stayed behind, none did. Being aware of some of the basics of physical geography has its advantages, and Mr. Kearney clearly had the attention of his students.

Newspaper editors could use some of this awareness. Many headlines referred to the tsunami as a tidal wave, but a tsunami has nothing to do with the tides that affect all oceans and seas. A tsunami results from an undersea earthquake involving a large displacement of the Earth's crust. Most submarine earthquakes do not generate tsunamis, but in some cases, fortunately relatively rarely, a large piece of crust is pushed up or pulled under (or both), and this causes the water overhead to pile up and start rolling away in all directions. If you were on a cruise ship somewhere in the middle of the ocean, nothing catastrophic would mark the passing of this tsunami wave; your ship would be lifted up and then lowered, but it would not overturn. But when such a huge wave reaches a beach, it does what all waves do: it breaks. Most of us have seen this happen with waves several feet (or even tens of feet) high. But imagine a wave over 200 feet high approaching a beach. As it begins to break, it pulls the water away, exposing wide swaths of muddy bottom. Then it comes crashing into the shore, pushing deep inland.

Tsunamis of the magnitude of 2004 occur rarely, but the hazard is continuous. As the Earth's human population has grown, so have the numbers of people vulnerable to such a calamity. As we learn more about the submarine zones where earthquakes are most likely to occur, we can begin to determine where the hazards are greatest. Here we combine two major fields of study in geography, physical geography and human geography. Geographers who work in this arena study human-environmental relationships—the reciprocal relationships between human societies and natural environments. Both, clearly, are dynamic. The environment is not a passive stage, and environmental change affects human societies. At the same time, humans have an impact on their natural environments. The study of hazards, not just from tsunamis but also from volcanic eruptions, terrestrial earthquakes, landslides, floods, avalanches, and other threats, is a key part of this research.

The tsunami that struck coasts along the Indian Ocean from Indonesia to Somalia and from Thailand to the Maldives resulted from a violent earthquake measuring more than 9.0 on the (10-point) Richter scale off the west coast of the island of Sumatra (Indonesia).

There, two of the planet's tectonic plates are colliding, forcing one beneath the other (Fig. 13.2). A continuous tremble of tremors and quakes affects the crust

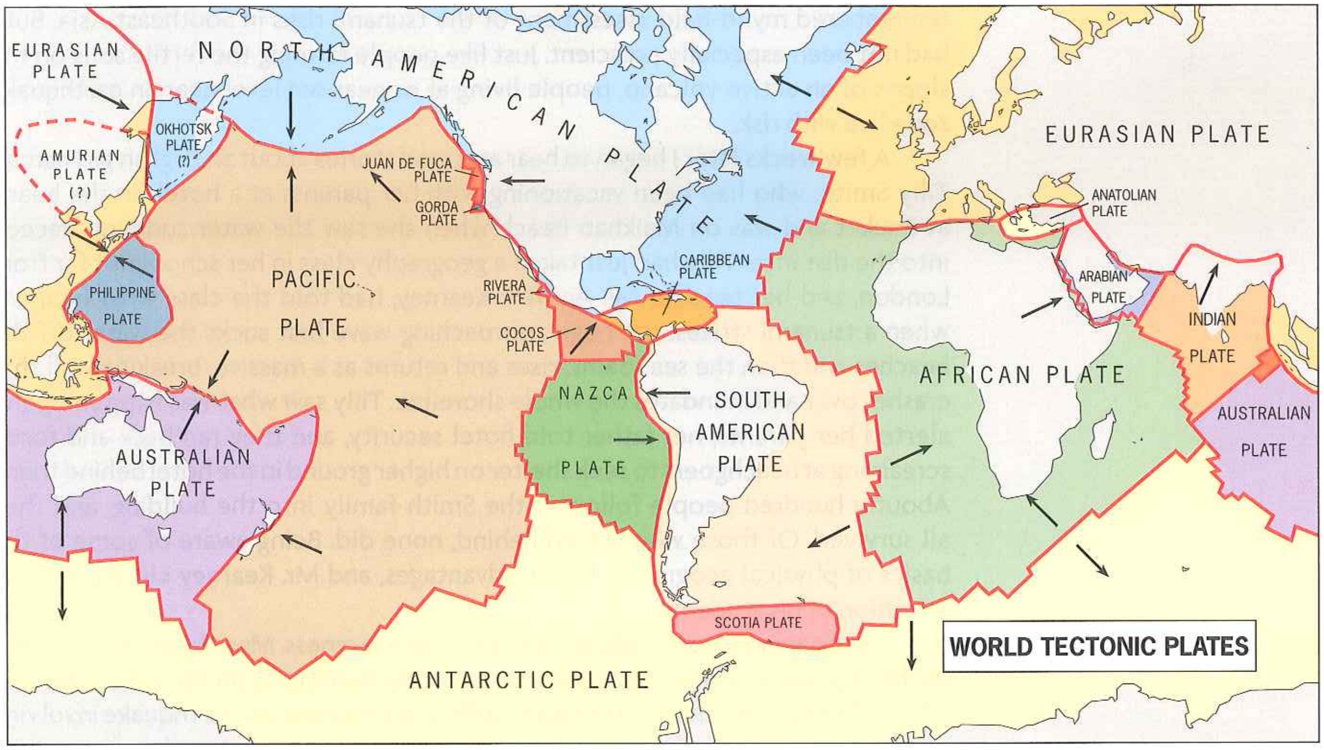


Figure 13.2
World Tectonic Plates. © H. J. de Blij, P. O. Muller, and John Wiley & Sons, Inc.

in such subduction zones, but sometimes a major shock occurs. In this case, the towering wave generated by the December 26 earthquake had but a short distance to travel to reach northern Sumatra, where it struck in full force. By the time it had done its damage in remote Somalia (in Africa), it had claimed approximately 300,000 lives and ruined the livelihoods of millions more. It illustrated the consequences of our planet's crowding and the impact of a global industry—the tourist industry—in drawing millions of tourists and workers to the very shores where vulnerability is highest.

Geography is a discipline in which the relationship between humans and the environment is a primary concern. One of the most influential nineteenth-century texts on this relationship, *Man and Nature* (1865), was written by the geographer George Perkins Marsh. In 1955, geographers were centrally involved in an international interdisciplinary symposium on "Man's Role in Changing the Face of the Earth." This symposium, like Marsh's earlier book, focused primarily on local and regional changes. More recently, a symposium led by geographers on "The Earth as Transformed by Human Action" picked up where the 1955 discussion left off, addressing global environmental changes. The geographer's concern with how things are organized on the Earth and how they are connected in space provides an analytical platform from which to consider human-induced environmental change.

As the study of environmental change has moved forward, one of the most important lessons we have learned is that global environmental systems are interconnected at numerous temporal and spatial scales. For example, the release of **chlorofluorocarbons** (CFCs) in Japan contributes to a growing hole in the Earth's ozone layer that is centered over Antarctica. Industrial production in the Netherlands and Germany contributes to acid rain in Scandinavia. The use of water from the Rio Grande for irrigation in northern New Mexico affects the amount and quality of the river's water that flows along the Texas-Mexico border. Human actions—the activities we undertake individually and collectively—are increasingly important factors in all sorts of global environmental changes. To confront these changes, we must consider the complex relationship between humans and the environment.

Key Questions For Chapter 13

1. How has the Earth environment changed over time?
2. How have humans impacted Earth's environment?
3. What are the major factors contributing to environmental change today?
4. How are humans responding to environmental change?

HOW HAS THE EARTH ENVIRONMENT CHANGED OVER TIME?

Environmental variation, spatial as well as temporal, is one of the Earth's crucial characteristics. Temperatures rise and fall, precipitation waxes and wanes. Forests flourish and wither, deserts expand and contract. Humanity has evolved during a series of alternatively warm and cold phases of an ice age that is still in progress. But today humanity itself is part of the process. The Earth has been warming, and we are probably contributing to this warmup. The world's governments are trying to find ways to combat industrial pollution and the release of greenhouse gases, gases that in the atmosphere cause warming.

Modern *Homo sapiens* emerged less than 200,000 years ago (and possibly not much more than 100,000 years ago). Virtually everything you have read about in this book—plant and animal domestication, state formation, urbanization, industrialization, and the diffusion of major world religions—has occurred over the past 10,000 years. This raises the question: how representative is the short-term present of the long-term past? Over the past century, geographers and other scientists have been engaged in a joint mission to reconstruct our planet's history on the basis of current evidence. One of them, the climatologist-geographer Alfred Wegener, used his spatial view of the world to make a key contribution. Viewing the increasingly accurate maps of the opposite coastlines of the North and South Atlantic oceans, he proposed a hypothesis that would account for the close "fit" of the shapes of the facing continents, which, he argued, would be unlikely to be a matter of chance. His continental drift hypothesis required the preexistence of a supercontinent, which he called **Pangaea**, that broke apart into the fragments we now know as Africa, the Americas, Eurasia, and Australia (Fig. 13.3). Wegener's hypothesis engendered the later theory of plate tectonics and crustal spreading, and scientists now know that Pangaea and its fragmentation were only the latest episodes in a cycle of continental coalescence and splintering that spans billions of years. This latest Pangaean breakup, however, began only 180 million years ago and continues to this day. Earthquakes and volcanic eruptions we hear about on the news usually take place along the boundaries of the crust's rocky plates.

During our brief presence on this planet, humans have had a powerful impact on environments ranging from rainforests to tundras. Long before we became technologically proficient we exterminated wildlife by the millions and burned grasslands and forests by the hundreds of thousands of square miles. The twentieth-century population explosion, combined with a rapid escalation in human consumption, magnifies humanity's impact on the Earth in unprecedented ways. Adjectives such as "calamitous" and "catastrophic" are often used to describe this impact, yet our planet has been the scene of calamities and catastrophes throughout its existence. *Homo sapiens* has not dominated this world long enough to have much experience with such events, but the environments with which we are familiar today result from long histories—and are temporary. Environmental change is a hallmark of Earth, and understanding long-term change helps us put the present in context and prepare for the future.

Ocean and Atmosphere

Earth today is often called the Blue Planet because more than 70 percent of its surface is covered by water and views from space are dominated by blue hues and swirls of white

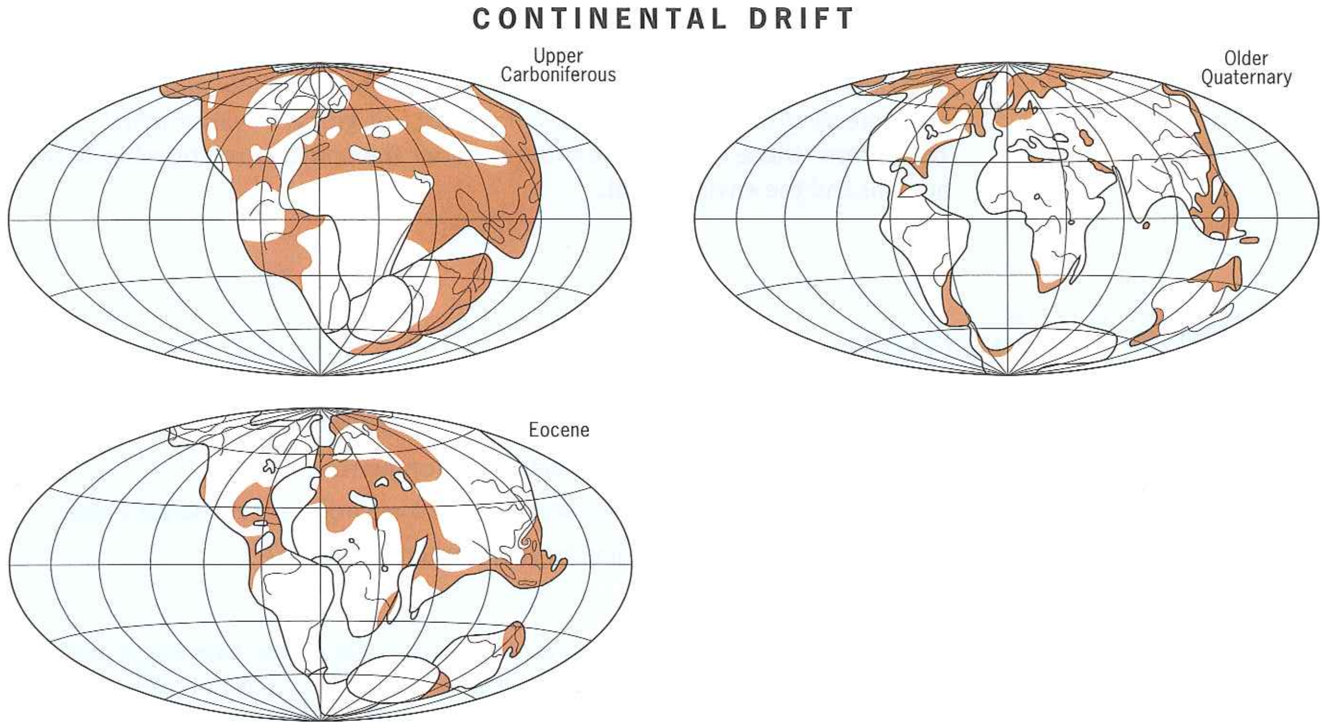


Figure 13.3
Wegener's Hypothesis of Continental Drift. Wegener's dates have been revised but were remarkably prescient. *Adapted with permission from:* Wegener, *The Origin of the Continents and Oceans*, 1914.

clouds. We do not know with any certainty how the Earth acquired its watery cloak or exactly when. Some scientists hypothesize that the water was originally trapped inside the Earth during its formation and rose to the surface during the time when heavier constituents sank to form the core. Others calculate that most of the water that did reach the surface in this way would have been evaporated into space by the searing heat then prevailing, suggesting that another source must be identified. This has led to the comet hypothesis, which proposes that icy comets bombarded the Earth for more than a billion years while its atmosphere was still thin, accumulating fresh water from space that filled the basins in the formative crust.

Neither do we know precisely how the atmosphere formed. Originally, the atmosphere was loaded with the gas carbon dioxide (CO_2), and if you could have looked up at the sky it would have been bright red because CO_2 scatters red light. Eventually, however, the primitive ocean, still heated from below, began to absorb CO_2 in huge quantities, depositing limestone and other carbonate rocks and turning the sky a familiar blue. Yet it was to be a very long time before oxygen became a substantial gas in the atmosphere. Around 1500 million years ago, green algae started to spread across the Earth's ocean surfaces, and as their colonies grew, their **photosynthesis** (the conversion of carbon dioxide and water into carbohydrates and oxygen through the absorption of sunlight) raised the atmosphere's oxygen content. About 800 million years ago, the oxygen content in the atmosphere was about one-twentieth of its present strength, or just 1 percent of the total. But that was enough to support the emergence of the first single-celled animals, the protozoa.

Fire and Ice

Today a major volcanic eruption is rare enough to make the news. Krakatoa (1883), Mount St. Helens (1980), Pinatubo (1991), and Etna (2001) took lives, damaged property, and, in the case of Pinatubo, even changed global climate slightly. One billion years ago, however, the Earth's crust was still immature and subject to huge bursts of volcanic activity. Such episodes poured incalculable volumes of gases and ash into the atmosphere, causing **mass depletions** (loss of diversity through a failure to produce new species) and contributing to the three **mass extinctions** (mass destruction of most species) known to have occurred over the past 500 million years.

The Earth's most recent experience with mass volcanism took place between 180 and 160 million years ago, when the supercontinent Pangaea began to fracture. Lava poured from fissures and vents as South America separated from Africa and India moved northeast. Skies were blackened, the atmosphere choked with ash. Animals responded as they always have in time of crisis: by migrating, fragmenting into smaller groups, and speeding up their adaptive, evolutionary response. Physical geographers hypothesize that the earliest phase of Pangaea's fragmentation was also the most violent, that the plate separations that started it all were driven by built-up, extreme heat below the supercontinent, but that the motion of the plates has since slowed down. The **Pacific Ring of Fire**—an ocean-girdling zone of crustal instability, volcanism, and earthquakes—is but a trace of the paroxysm that marked the onset of Pangaea's breakup (Fig. 13.4). Yet, as we saw with the tsunami in December 2004, tectonic events have cost millions of humans their lives and altered the course of history.

When Pangaea still was a supercontinent, an Ice Age cooled the Earth and may have contributed to, if not caused, the greatest known extinction crisis in the history of life on Earth. Ice Ages are not uniform cooling events: surges of coldness and advances of glaciers are interrupted by temporary warming spells long enough to reverse much of the glacial impact. By the time the **Pleistocene** epoch opened, less than 2 million years ago, the planet was in a deep freeze.

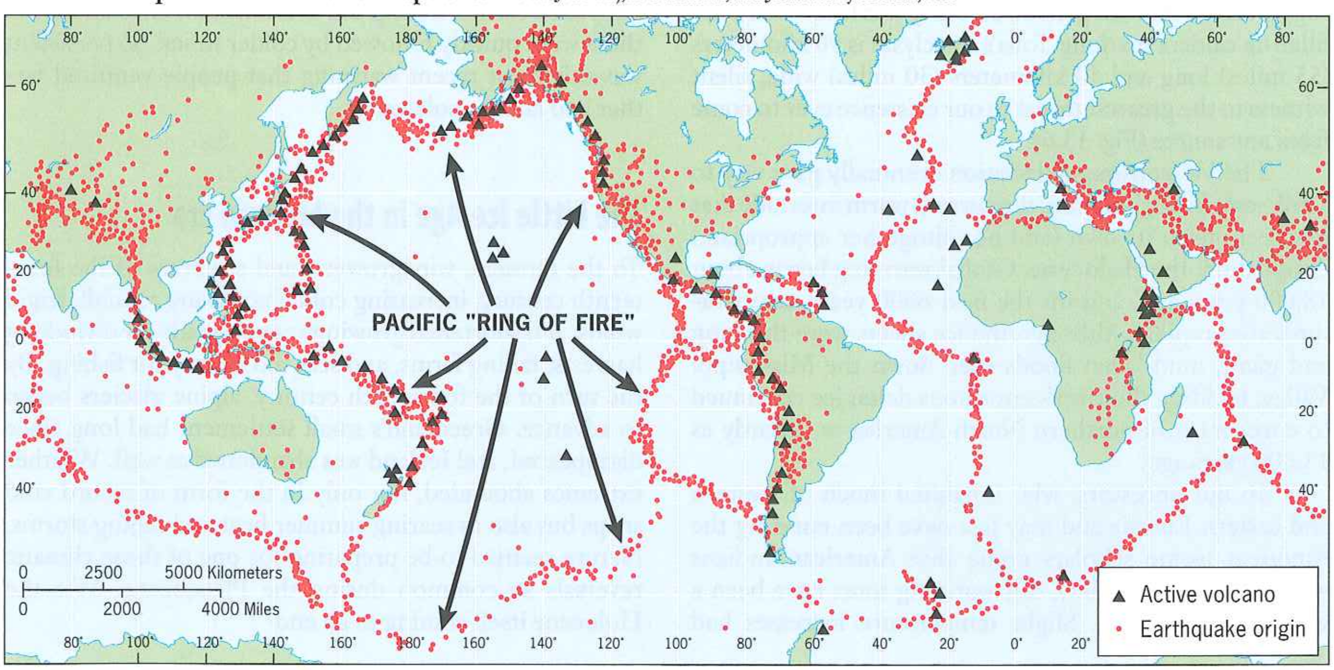
The Pleistocene was an epoch marked by long **glaciations** and short, warm **interglaciations**. When the Pleistocene glaciations were most severe, permanent ice advanced deep into the landmasses of the Northern Hemisphere. Plants, animals, and hominids saw their living space diminished, their refuges shrunk, their niches unusable. Such glaciations could last as long as 100,000 years, but eventually a warming spell would arrive, the ice would recede, and space as well as opportunity expanded again. A warming phase of this kind occurred between about 120,000 and 100,000 years ago, and some scientists suggest that this is the time when *Homo sapiens* appeared on the Earth.

The most recent glaciation of the Pleistocene, the **Wisconsin Glaciation**, left its mark on much of the Northern Hemisphere (Fig. 13.5). But resourceful humans managed to survive where their predecessors could not, and there is ample evidence of human occupation in Europe ranging from cave art to tool kits. Even during a glacial advance brief periods of milder climate emerge. Thus, Figure 13.5 represents a glacial extreme, not the whole picture. So human communities—fishing, hunting and gathering, and using increasingly sophisticated tools (and probably means of verbal communication)—exploited the milder times by expanding their frontiers.

About 73,500 years ago, something happened that came close to exterminating humanity altogether. A volcano, Mount Toba, erupted on the Indonesian island of Sumatra. This was not just an eruption: the entire mountain exploded, sending millions of tons of debris into orbit, obscuring the sun, creating long-term darkness, and altering global climate. Mount Toba's detonation could hardly have come at a worse time. The Earth's habitable zone was already constricted because of glaciation. Anthropologists refer to this event as humanity's "evolutionary bottleneck,"

Figure 13.4

Recent Earthquakes and Volcanic Eruptions. © H. J. de Blij, P. O. Muller, and John Wiley & Sons, Inc.



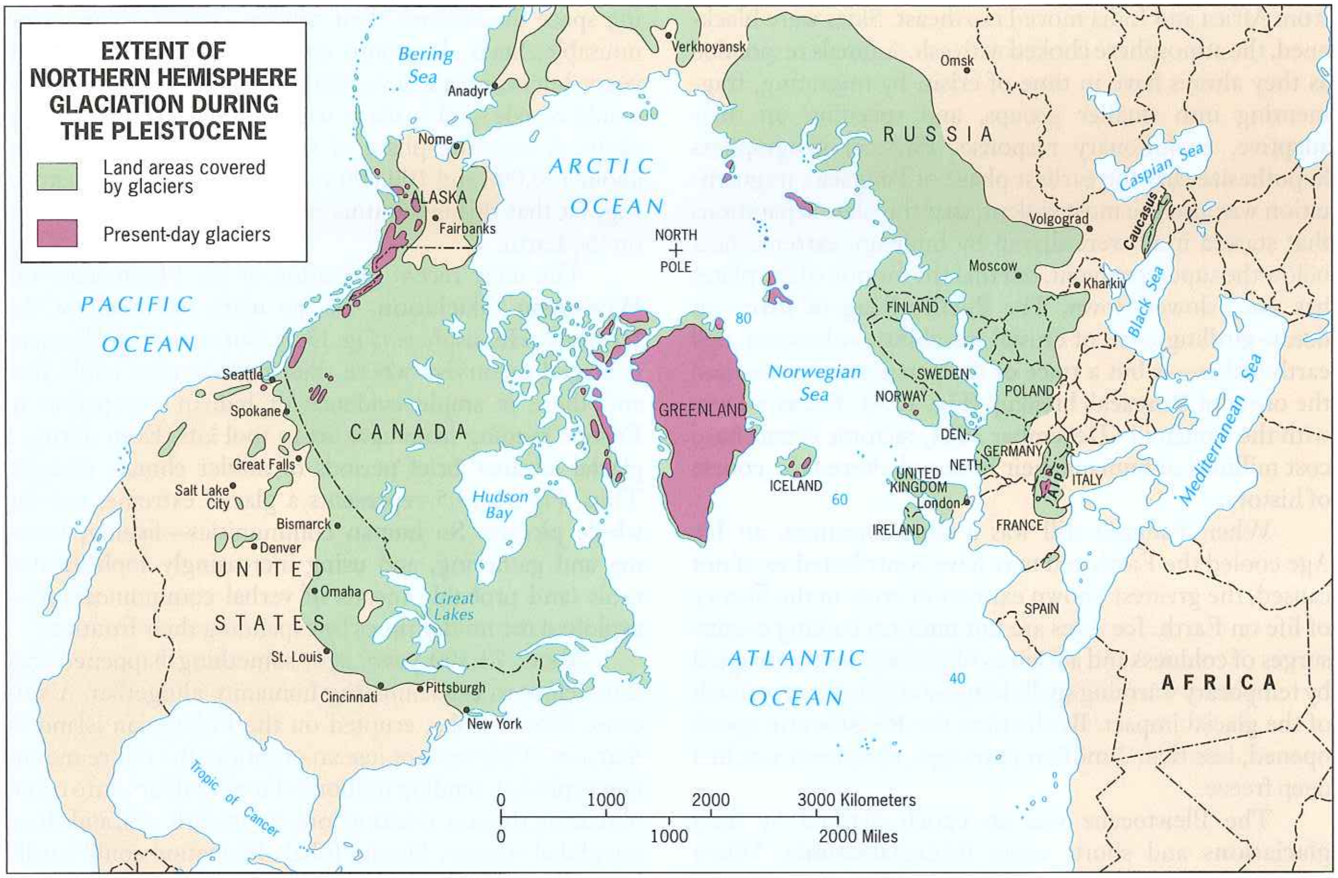


Figure 13.5
Extent of Northern Hemisphere Glaciation During the Late Pleistocene's Wisconsinan Glaciation. The evidence on which this map is based includes glacial deposits and the marks of glaciers' erosion on bedrock. © H. J. de Blij, P. O. Muller, and John Wiley & Sons, Inc.

suggesting that much genetic diversity was lost. Today, the filled-in caldera marking Toba's cataclysm is 90 kilometers (55 miles) long and 50 kilometers (30 miles) wide, silent witness to the greatest threat to our existence ever to come from any source (Fig. 13.6).

The Wisconsinan Glaciation eventually gave way to a full-scale interglaciation, the current warm interlude that has been given its own (and not altogether appropriate) designation, the **Holocene**. Global warming began about 18,000 years ago, and for the next 6000 years, temperatures rose rapidly. Although the ice sheets were thinning and giant, mud-laden floods sped down the Mississippi Valley, building the river's enormous delta; ice continued to cover most of northern North America as recently as 13,000 years ago.

To our ancestors, who inhabited much of western and eastern Eurasia and may just have been entering the Americas (some scholars argue that American Indians were here much earlier), this warming must have been a welcome experience. Slight temperature increases had happened earlier, during the Wisconsinan Glaciation, but these were quickly followed by colder times. So persistent was this most recent warming that people ventured farther and farther poleward.

The Little Ice Age in the Modern Era

To the farmers, winegrowers, and seafarers of the fourteenth century, increasing cold, decreasing rainfall, frigid winds, and shortened growing seasons made for dwindling harvests, failing farms, and seas too stormy for fishing. By the turn of the fourteenth century, alpine glaciers began to advance. Greenland's small settlement had long since disappeared, and Iceland was abandoned as well. Weather extremes abounded, not only in the form of record cold snaps but also as searing summer heat and raging storms. Nature seemed to be preparing for one of those climatic reversals so common during the Pleistocene. Was the Holocene itself coming to an end?

Figure 13.6
Mount Toba, Indonesia. The lake in this photo fills in the gigantic caldera left from the eruption of Mount Toba on the island of Sumatera in Indonesia. © A. M. & K. D. Hollitzer/Asiafoto.

Famines struck all over Europe, just at a time when more people were clustered in towns than ever before. The climatic record, pieced together from farmers' diaries (winegrowers' diaries are especially useful), tree ring research (dendochronology), ice cores, contemporary writings, illustrative paintings, and surviving sketches and drawings, justify the designation of the post–1300 period as a shift in the direction of reglaciation. We now know that this return to colder times, marked by advancing mountain glaciers and thickening Subarctic ice, would end in the mid-nineteenth century and that even the worst of it, starting in the late 1600s, did not lead to full-scale Pleistocene glaciation. Whatever was happening precipitated serious social disruptions in Europe and in other parts of the world as well, but of course those who experienced it were unaware of the long-term implications. Only when new methods of analysis became available did scientists realize what had happened—and then they gave the episode an inappropriate name. This temporary cooling was no ice age: it was a minor glaciation and not the first over the past 6000 years. But the name **Little Ice Age** certainly was more dramatic than "Minor Glaciation," and it stuck.

To those affected, it was anything but little or minor. Europe's climate fluctuated wildly, often over relatively short periods of time, so that recovery would be followed by renewed famine; populations mushroomed and then fell back again. In the fourteenth century, the human geography of eastern and western Eurasia became fatally interlocked. The salubrious conditions that enabled Mongol peoples to thrive and expand, leading to a Mongol dynasty in China, also facilitated their penetration westward. In the process, Mongol migrants and their horse caravans picked up the strain of bacteria that brings on the bubonic plague, and its vector, the flea, rode into Europe. The Black Death swept over an already weakened Europe in waves that often killed half the population or more. Recovery, medical as well as environmental, did not start until the last quarter of the fifteenth century.

In China, meanwhile, the full impact of the Little Ice Age occurred after the end of the Mongol (Yuan) dynasty (1368). The early Ming rulers inherited a populous state sustained by wheat in the north and rice in the center, linked by the Grand Canal and other busy waterways. Late in the fourteenth century the Ming rulers, exhorted by the legendary admiral Chung Ho, authorized the construction of an oceangoing fleet that would stake China's claim and enhance its reputation in the Indian Ocean and beyond. The fleet eventually numbered more than 6000 ships, the largest carrying as many as 500 people; these were 400 feet long, had four decks and nine masts, and carried sufficient fresh water and supplies to sail for 20 days. Nothing built in Europe even began to approach these vessels in terms of technology or capacity—the first expedition, in 1405, involved 315 ships and 27,000 people. Later voyages reached the Persian Gulf and the Red Sea as well as East Africa, possibly as far south as Sofala. The Chinese seemed poised to round the Cape of Good Hope and enter the Atlantic.

But then disaster struck at home. The first onslaught of the Little Ice Age came later than it did in Europe, but it was no less severe. Interior rains failed, rivers dried up, the wheat crop shrank, famines broke out, and social disorder and epidemics raged. The Ming rulers ordered an end to the maritime expeditions, dictated the burning of all oceangoing vessels, and instructed the Nanjing shipyard, then by far the largest in the world, to build only barges that could navigate the Grand Canal with cargoes of rice, thus alleviating the plight of the colder, drier north. Environments do not determine the capacities of humans, but environmental events can certainly influence the course of history.

In his book *The Little Ice Age* (2000), archaeologist Brian Fagan describes how the Franz Josef Glacier on New Zealand's South Island "thrust downslope into the valley below, smashing into the great rainforests... felling giant trees like matchsticks." In North America, our growing understanding of the Little Ice Age helps explain why the Jamestown colony collapsed so fast, a failure attributed by historians to ineptitude and lack of preparation. The chief cause may well have been environmental. Geographer David Stahle (1998) and his team, studying tree ring records that go back eight centuries, found that the Jamestown area experienced a seven-year drought between 1606 (the year before the colony's founding) through 1612, the worst in nearly eight centuries. European colonists and American Indians were in the same situation, and their relations worsened as they were forced to compete for dwindling food and falling water tables. The high rate of starvation was not unique to the colonists. They, and their American Indian neighbors, faced the rigors of the Little Ice Age as well.

As the Little Ice Age continued into the 1800s, a large-scale volcano had a major impact on human society. On April 5, 1815, the Tambora Volcano on the island of Sumatera in what was then the Dutch East Indies, located not far East of Bali, rumbled to life. Less than a week later it was pulverized in a series of explosions that could be heard a thousand miles away, killing all but 26 of the island's population of 12,000. When it was over, the top 4000 feet of the volcano were gone, and much of what is now Indonesia was covered by debris. Darkness enveloped most of the colony for weeks, and tens of thousands died of famine in the months that followed. Colonial reports describe fields covered by poisonous ash and powder, waters clogged by trees and cinders, and air rendered unbreathable by a fog of acid chemicals.

Tambora's explosions rocketed tens of millions of tons of ash into orbit, darkening skies around the world. What began as a narrow equatorial band of ash and dust gradually widened into a globe-girdling membrane that blocked part of the sun's radiation. By the middle of 1816, it was clear to farmers everywhere that this would be a year without summer, a growing season without growth. In Europe, food shortages were acute and grain prices rose rapidly, forcing governments to close their borders to prevent speculation. Food riots nevertheless broke out in the towns, and in the countryside armed gangs raided farms and stores. In the United States, the "year without summer" was especially difficult on the farms of New England, where corn would not ripen, grain prices escalated, and the livestock market collapsed. We can only guess at the impact of Tambora's eruption in other parts of the world, but there can be no doubt that 1816 was a desperate year—a crisis that reminds us of the risks under which all of humanity lives.

Since the 1850s, when the Little Ice Age waned and a slow but nearly persistent warming phase began, climatologists and other scientists have learned much about the workings of our planet, but they do not yet know enough to be able to make reliable predictions about what will happen.

thinking geographically

Take time to search the Internet and read about what has happened to Phuket, Thailand, since the Indian Ocean tsunami hit in December 2004. Look for before and after images of Phuket—how did it look before the tsunami hit and after? Research how Phuket has been rebuilt and determine why Phuket has been rebuilt the way it has.

HOW HAVE HUMANS IMPACTED EARTH'S ENVIRONMENT?

Biologists estimate that there may be as many as 25 million types of organisms on Earth, perhaps even more; most have not yet been identified, classified, or studied. *Homo sapiens* is only one of these, yet in ten millennia our species has developed a complex culture that is transmitted from one generation to the next through learning and is also to some degree encoded in our genes. Humans are not unique in possessing a culture: gorillas, orangutans, chimpanzees, and dolphins have cultures too. Ours is the only species, however, with a vast and complex array of artifacts, technologies, laws, and belief systems.

No species, not even the powerful dinosaurs, ever affected their environment as strongly as humans do today. A cometary impact probably made the dinosaurs and many other species extinct. Some biogeographers suggest that the next great extinction may be caused not by asteroids but by humans, whose numbers and demands are destroying millions of species.

Alteration of Ecosystems

Destructiveness is not just a matter of modern technology and its capacity to do unprecedented damage, whether by wartime forest defoliation, peacetime oil spills, or other means. Humans altered their environment from the beginning, when they set fires to kill herds of reindeer and bison, or hunted entire species of large mammals to extinction. The Maori, who arrived in New Zealand not much more than 1000 years ago, greatly altered native species of animals and plants long before the advent of modern technology. Elsewhere in the Pacific realm, Polynesians reduced the forest cover to brush and, with their penchant for wearing bird-feather robes, had exterminated more than 80 percent of the regional bird species by the time the first Europeans arrived. The Europeans ravaged species ranging from Galapagos turtles to Antarctic seals. European fashions had a disastrous impact on African species ranging from snakes to leopards. Traditional as well as modern societies have had devastating impacts on their ecosystems (ecological units consisting of self-regulating associations of living and nonliving natural elements) as well as on those of areas into which they migrated.

Human alteration of the environment continues in many forms today. For the first time in history, however, the combined impact of humanity's destructive and exploitative actions is capable of producing environmental changes at the global scale. Consider for a moment the history of human life on Earth. Early human societies had relatively small populations, and their impacts on the physical environment were limited in both duration and intensity. With the development of agrarian and preindustrial societies, human alterations of the physical environment increased, yet the effects of these early activities were still limited in scale. Even the onset of urbanization and the development of urban centers, which concentrated large numbers of people in particular places, had relatively limited effects. Over the last 500 years, however, both the rate and the scale at which humans modify the Earth have increased dramatically. Particularly during the last half-century, every place on earth has been transformed, either directly or indirectly, by humans.

Environmental Stress

The natural environment is being modified and stressed by human activity in many obvious and some less obvious ways. Among the more obvious actions (obvious because they take place around human habitats) causing **environmental stress** are the cutting of forests and the emission of pollutants into the atmosphere. Less obvious actions include the burying of toxic wastes that foul groundwater supplies, the dumping of vast amounts of garbage into the oceans, and the use of pesticides in farming. Humans have built seawalls, terraced hillslopes, dammed rivers, cut canals, and modified the environment in many constructive as well as destructive ways. All of these activities have an impact on the environment and have given rise to a number of key concerns. Among these are the future of water supplies, the state of the atmosphere, climate change, desertification, deforestation, soil degradation, and the disposal of industrial wastes.

Water

Resources that are replenished even as they are being used are **renewable resources**, and resources that are present in finite quantities are nonrenewable. Water, the essence of life, is a renewable resource. But the available supply of fresh water is not distributed evenly across the globe. Figure 1.10 shows the world distribution of precipitation, with the largest totals recorded in equatorial and tropical areas of Southeast Asia, South Asia, Central and coastal West Africa, and Middle and South America. That distribution is sustained through the **hydrologic cycle**, which brings rain and snow from the oceans to the landmasses (Fig. 13.7). The volume of precipitation in the world as a whole is enormous; spread out evenly, it would cover the land area of the planet with about 83 centimeters (33 inches) of water each year. Much of that water is lost through runoff and evaporation, but enough of it seeps downward into porous, water-holding rocks called **aquifers** to provide millions of wells with steady flows. In the United States alone, it is estimated that there is 50 times as much water stored in aquifers as there is precipitation falling on the land surface every year.

Despite such favorable data, the supply of water is anything but plentiful (Fig. 13.8). Chronic water shortages afflict tens of millions of farmers in Africa and hundreds of thousands of city dwellers in Southern California; water rationing has been imposed in rainy South Florida and in Spain, which faces the Mediterranean Sea.

In many areas of the world, people have congregated in places where water supplies are insufficient, undependable, or both. In California, people are sometimes not allowed to wash their cars or refill their swimming pools; these are minor inconveniences compared to the fate faced by millions of Sudanese trying to escape their country's civil war by fleeing to parched pans of the Sahara. In Florida, where the urban population depends on the Biscayne Aquifer for most of its water, the long-term prospect is troubled: whenever seasonal rainfalls do not reach their projected averages, Floridians overuse the Biscayne Aquifer, and saltwater enters the aquifer from the nearby Atlantic Ocean. The invasion of saltwater over time can permanently destroy a fresh water aquifer.

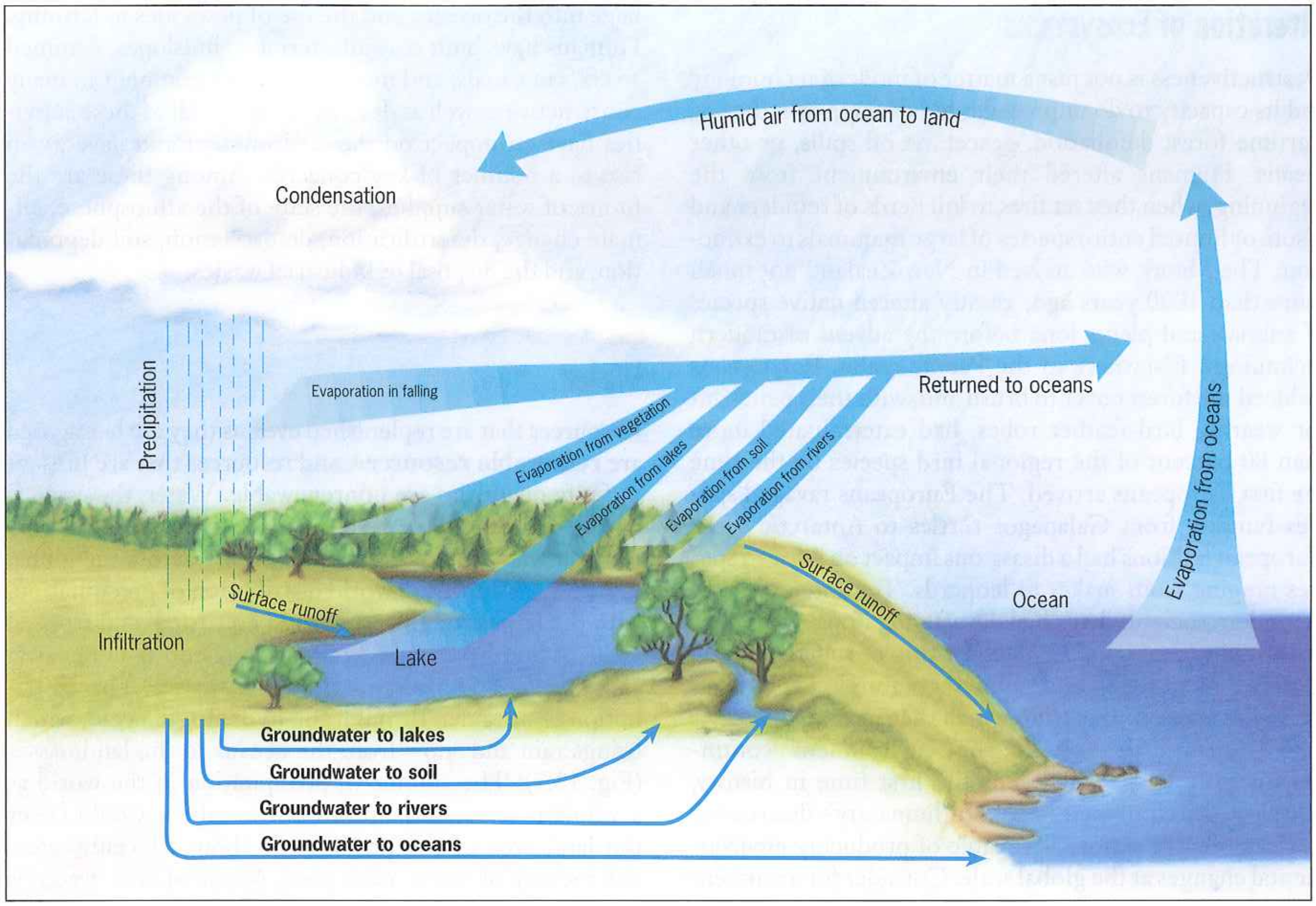


Figure 13.7

The Hydrologic Cycle. The hydrologic cycle carries moisture from the oceans and from other water bodies over the land, where precipitation, runoff, and evapotranspiration sustain the system. © E. H. Fouberg, A. B. Murphy, H. J. de Blij, and John Wiley & Sons, Inc.

Field Note

"We drove north on Route 89 from Tucson, Arizona, across the desert. Drought rules the countryside here, and dams conserve what water there is. Snaking through the landscape are lifelines such as this, linking Coolidge Dam to distant farms and towns. In the vast, arid landscape, this narrow ribbon of water seems little more than an artificial brook—but to hundreds of thousands of people, this is what makes life possible in the Southwest."

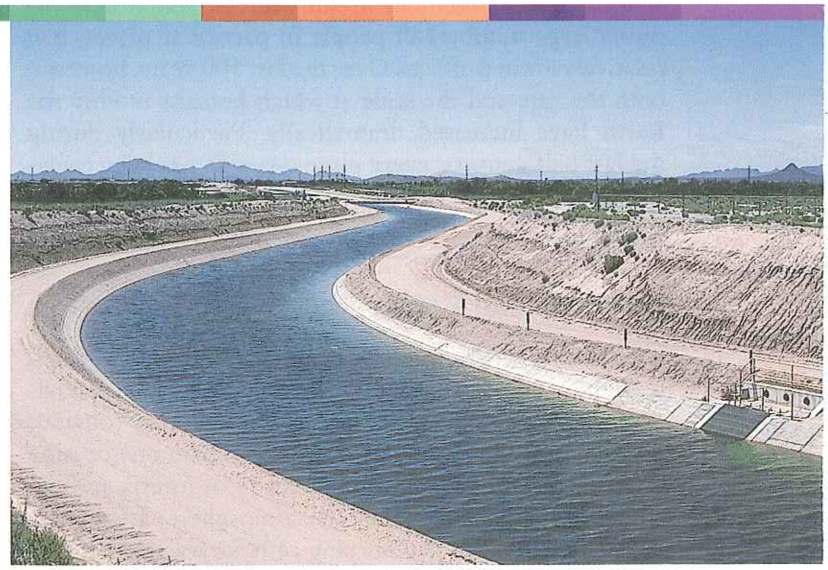


Figure 13.8

Tucson, Arizona. © H. J. de Blij.

Hundreds of millions of people still cluster along several of the Earth's great rivers. Indeed, nearly three-quarters of all the fresh water used annually is consumed in farming, not in cities. In California, where about 80 percent of available water is used for irrigation, this has led to an intense debate: should cities be provided with ample water at the expense of Central Valley farms, and should fruits and vegetables be bought from elsewhere, even overseas, rather than be grown locally?

Industries use another 20 percent of the world's water supply, contributing heavily to pollution when the used water is returned to streams, lakes, and aquifers. When communist rule ended in Eastern Europe, tests indicated that the region's rivers and groundwater were among the most severely polluted in the world because industries there had not been adequately regulated.

As human populations have expanded, people have increasingly settled in arid regions. One of the great ecological disasters of the twentieth century occurred in Kazakhstan and Uzbekistan, whose common boundary runs through the Aral Sea. Streams that fed this large body of water were diverted to irrigate the surrounding desert (mainly for commercial cotton production). Heavy use of chemical pesticide ruined the groundwater below, causing a health crisis that some observers describe as an "ecological Chernobyl" (referring to the 1986 nuclear reactor meltdown in the Ukraine). In the meantime the Aral Sea began to dry up, and by the mid-1990s it had lost more than three-quarters of its total surface area (Fig. 13.9).

Throughout the world, people have come to depend on water sources whose future capacity is uncertain. Rocky Mountain and Sierra Nevada snows feed the Colorado River and the aquifers that irrigate the California Central Valley. Aqueducts snake their way across the desert to urban communities. None of this slows the population's move to the Sunbelt (see Chapter 12), and the water situation there is becoming problematic. In coastal eastern Spain, low water pressures in city pipes often deprive the upper floors of high-rise buildings of water. In Southwest Asia and the Arabian Peninsula, growing populations strain ancient water supply systems and desalinization plants are a necessity. Regional conflicts in places such as Sudan (especially the Darfur region of Sudan) are fueled by conflicts over water.

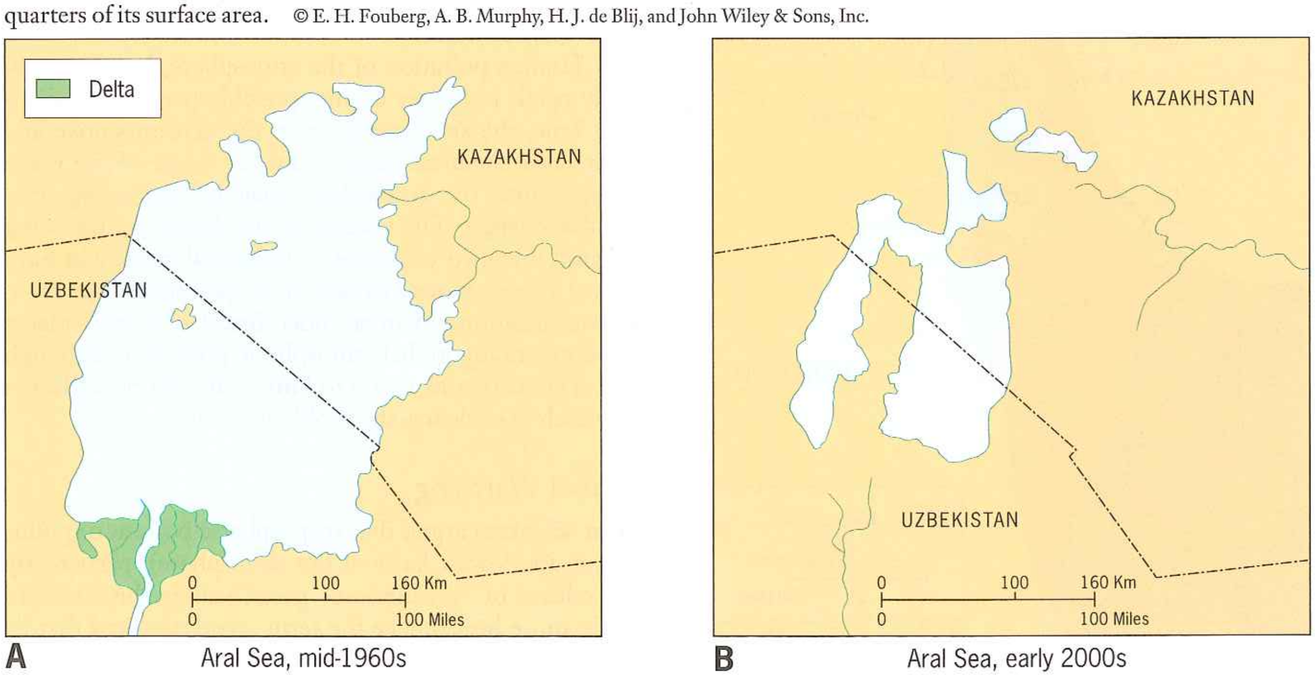
Water and Politics in the Middle East

When relations between countries and peoples are problematic, disputes over water can make them even worse. As populations grow and as demand for water rises, fears of future shortages intensify.

Water supply is a particularly difficult problem affecting relations among Israel and its neighbors. With under 6 million people, Israel annually consumes nearly three times as much water as Jordan, the West Bank Palestinian areas, and Gaza combined (total population: over 7 million). As much as half of Israel's water comes from sources outside the Israeli state.

Figure 13.9

The Dying Aral Sea. Affected by climatic cycles and afflicted by human interference, the Aral Sea on the border of Kazakhstan and Uzbekistan is dying. In a quarter of a century, it lost three-quarters of its surface area.



The key sources of water for the entire area are the Jordan River and an aquifer beneath the West Bank. When Israel captured the Golan Heights from Syria and the West Bank from Jordan during the 1967 war, it gained control over both of these sources, including the Jordan River's important tributary, the Yarmuk (Fig. 13.10). As the map shows, the Sea of Galilee forms a large fresh water reservoir in the Jordan River Valley. This is the source of most of Israel's water (desalinization facilities do not yet contribute significantly).

The water supply complicates the relationships between Israel and its Palestinian neighbors in the West Bank and Gaza. The aquifer beneath the West Bank yields about 625 million cubic meters through hundreds of wells linked together by a system of pipelines. Of this, some 450 million cubic meters go directly to Israel; another 35 million are consumed by Israeli settlers on the West Bank, and only some 140 million are allotted to the West Bank's nearly 2 million Arabs.

This is unfair, say the Palestinian Arabs: if the West Bank is to become independent Palestinian territory, the water below the surface should belong to the Palestinians.

Figure 13.10
Key Water Resources in the Middle East. © E. H. Fouberg, A. B. Murphy, H. J. de Blij, and John Wiley & Sons, Inc.

But the Israeli cities of Tel Aviv and Jerusalem depend heavily on water from the West Bank, and Israel cannot survive without this source.

The water issue will complicate any hoped-for settlement of territorial disputes among Israel and its neighbors. Israel might contemplate the return of most of the Golan Heights to Syria, but about 30 percent of all water reaching the Sea of Galilee comes from the Golan Heights. Israel might support the establishment of an independent state in the West Bank, but approximately 30 percent of Israel's water supply comes from the West Bank aquifer. Any effort to negotiate a lasting peace in the region will have to take these geographical circumstances into account.

Atmosphere

The Earth's **atmosphere** is a thin layer of air lying directly above the lands and oceans. We depend on the atmosphere for our survival: we breathe its oxygen; it shields us from the destructive rays of the sun; it moderates temperatures; and it carries moisture from the oceans over the land, sustaining crops and forests and replenishing soils and wells.

The atmosphere has a truly amazing capacity to cleanse itself. In 1883 the Indonesian volcano Krakatau erupted catastrophically, throwing 10 cubic kilometers (2.5 cubic miles) of rock and ash into the atmosphere. Total darkness prevailed in the area for nearly three days; dust from the explosion encircled the Earth and created vividly colored sunsets for years afterward. However, eventually the atmosphere cleared, and all traces of the eruption disappeared. In 1980 the eruption of Mount St. Helens in the northwestern United States caused a similar, though much smaller, globe-encircling cloud of volcanic dust in the upper atmosphere. Again, the atmosphere soon cleansed itself.

Human pollution of the atmosphere, however, will likely result in longer lasting, possibly permanent, damage. True, the air disperses even the densest smoke and most acrid chemical gases. However, some of the waste pouring into the atmosphere may be producing irreversible change. The nature of the change is still being debated, but two centuries of industrial expansion have caused an enormous increase in the pollution. The rapid industrialization of China, India, Brazil, and other places is compounding global atmospheric pollution. Although global concern and action to limit atmospheric pollution are much in evidence, the problem remains.

Global Warming

Most scientists argue that tropospheric pollution (pollution in the lowest layer of the atmosphere), particularly the release of "greenhouse" gases, causes the Earth to retain more heat (hence the term *greenhouse*) and that its full effect will not be felt until well into the twenty-first century. Estimates of **global warming** differ: in the early 2000s computer models still predicted a warming of 2.7°C to 3.7°C (about 3.57°F to 5.57°F) over the next 50 years. This might be enough to melt some glacial ice and raise sea levels as much as 15 centimeters (6 inches). Indeed, this is already happening, as evidenced by the disappearance of two uninhabited Islands in the pacific atoll state of Kirinati.

Moreover, changes in climate involve changes in the hydrologic cycle, affecting patterns of precipitation. These changes in turn can affect where certain types of vegetation can grow, which can alter everything from agricultural patterns to the location of animal habitats.

Although there is some debate about how much the earth will warm, there is no question that growing populations and increased human activity, ranging from the burning of tropical forests to pollution of the atmosphere by industry and automobiles, are having an unprecedented impact on the atmosphere. The amounts of key "greenhouse" gases, carbon dioxide (CO_2), methane, and nitrous oxides in the atmosphere have been increasing at a rate of about 2 percent per decade; automobiles, steel mills, refineries, and chemical plants account for a large part of this increase. Without doubt there will be consequences; all that remains uncertain is exactly what those consequences will be.

Acid Rain

A by-product of the enormous volume of pollutants spewed into the atmosphere is **acid rain**. Acid rain forms when sulfur dioxide and nitrogen oxides are released into the atmosphere by the burning of fossil fuels (coal, oil, and natural gas). These pollutants combine with water vapor in the air to form dilute solutions of sulfuric and nitric acids, which then are washed out of the atmosphere by rain or other types of precipitation, such as fog and snow.

Although acid rain usually consists of relatively mild acids, it is caustic enough to harm certain natural ecosystems (the mutual interactions between groups of plant and animal organisms and their environment). Already we know that acid rain is causing acidification of lakes and streams (with resultant fish kills), stunted growth of forests, and loss of crops in affected areas. In cities, corrosion of buildings and monuments has accelerated.

The geography of acid rain is most closely associated with patterns of industrial concentration and middle- to long-distance wind flows. The highest densities of coal and oil burning are associated with large concentrations of heavy manufacturing, such as those in western and eastern Europe, the United States, and Eastern China. As these industrial areas began to experience increasingly severe air pollution problems in the second half of the twentieth century, many countries (including the United States in 1970) enacted legislation establishing minimal clean-air standards.

In the United States and western Europe, compliance with legislated emission reductions is having positive results. In Canada as well as in Scandinavia, where acid rain from neighboring industrial regions damaged forests and acidified lakes, recovery came faster than scientists had predicted. This evidence is now encouraging other countries to impose stricter controls over factory emissions.

The Land

Over the centuries, human population growth has put increasing pressure on the land surface. More land is cleared and placed under cultivation, trees are cut down, and cities expand. The effects can be seen almost everywhere and are so extensive that it is often difficult even to reconstruct what an area might be like in the absence of humans. The human impact on the Earth's land surface has several key aspects, of which the most significant are deforestation, soil erosion, waste disposal (discussed here) and biodiversity less.

Deforestation

From the tropical Amazon Basin to high-latitude North America and Eurasia, humans have cut down forests and whittled away woodlands.

The world's forests, especially those of lower and middle latitudes, play a critical role in what biogeographers call the **oxygen cycle**. Atmospheric oxygen is consumed by natural processes as well as by human activities. Forests counteract this loss through photosynthesis and related processes, which release oxygen into the atmosphere. The destruction of vast tracts of forest alarms ecologists and others, who warn of unforeseeable and incalculable effects—not only for the affected areas but for the planet as a whole.

In the early 1980s, the Food and Agriculture Organization (FAO) of the United Nations undertook a study of the rate at which forests were being depleted. This analysis showed that 44 percent of the tropical rainforest had already been affected by cutting and that more than 1 percent was being logged every year (Fig. 13.11). In 1990, the FAO predicted that if this rate of cutting were to continue, the entire equatorial rainforest would be gone in less than 90 years.

In 2005, the FAO released a comprehensive, ten-year study of the world's forests. It found that the annual net loss of forests globally was 7.3 million hectares/year between 2000 and 2005—a rate that was lower than the 8.9 million hectares/year between 1990 and 2000.

Field Note

"This was one of the most depressing days of this long South American field trip. We had been briefed and had seen the satellite pictures of the destruction of the rainforest, with ugly gashes of bare ground pointing like rows of arrows into the woods. But walking to the temporary endpoints of some of these new roads made a lot more impact. From the remaining forest around came the calls of monkeys and other wildlife, their habitat retreating under the human onslaught. Next week this road would push ahead another mile, the logs carted away and burned, the first steps in a process that would clear this land, ending billions of years of nature's dominance."

Figure 13.11
Para, Brazil. © H. J. de Blij.

Deforestation is not a singular process: it has been going on for centuries, and the motivations for deforestation vary vastly. Forests are cut and reforested for wood and paper products; forests are preserved for the maintenance of biodiversity; and other forests are cleared for new agricultural production.

The effects of **deforestation** are not clearly understood. The reforestation (and harvesting) of deforested areas is not the whole answer, even if it could be done on a large scale. Forests in the United States, for example, consist mainly of second-growth trees, which replaced the original forest after it was logged. However, the controlled second-growth forest does not (as the natural forest did) have many trees dying of old age after their trunks and limbs become soft from rot. As a result, many animal species that depend on holes in trunks and hollows in tree limbs cannot find places to nest (thus, the spotted owl dispute in the Pacific Northwest of the United States). For them the forest has ceased to be a favorable habitat.

Soil Erosion

The loss of potentially productive soil to erosion has been described as a "quiet crisis" of global proportions. Ecologists Lester Brown and Edward Wolf point out that the increasing rate of this loss over the past generation is not the result of a decline in the skills of farmers but rather of the pressures on farmers to produce more. In an integrated world food economy, the pressures on land resources are not confined to particular countries; they permeate the entire world.

Why has **soil erosion** increased so much? Part of the answer lies in population pressure: world population is moving toward 7 billion. Associated with population growth is the cultivation of ever-steeper slopes, with hastily constructed terraces or without any terraces at all (Fig. 13.12). As the pressure on land increases, farmers are less able to leave part of their soil fallow (unused) to allow it to recover its nutrients. Shifting cultivators (see Chapter 11) must shorten their field rotation cycle, and as a result their soil, too, is less able to recover. Altogether 99.7 percent of all human food is grown in soil (some is grown in water), and annual soil erosion shrinks the cropland available for agriculture. A 2006 study reported that globally about 37,000 square miles (10 million hectares) of cropland are lost to soil erosion each year.

Soil erosion is caused by a variety of factors: livestock are allowed to graze in areas where they destroy the natural vegetation; lands too dry to sustain farming are plowed, and wind erosion follows. Soil is a renewable resource because with proper care it can recover. However, it is being "mined" as if it were a nonrenewable resource. International cooperation in food distribution, education of farmers and governments, and worldwide dissemination of soil conservation methods are urgently needed to solve this "quiet crisis."

Waste Disposal

If anything has grown faster than population itself, it is the waste generated by households, communities, and industries—much of it a matter of bulk, some of it a source of danger.

The United States, the world's largest consumer of resources, is also the largest producer of **solid waste**, debris, and garbage discarded by those living in cities, industries, mines, and farms. According to current estimates, the United States produces about 1.7 kilograms

Figure 13.12
Guangxi-Zhuang, China. Overuse of land in this area of China was leading to the collapse of formerly sound terracing systems. © H. J. de Blij.

(3.7 pounds) of solid waste per person per day, which adds up to well over 160 million metric tons (just under 180 million tons) per year. But the United States is not alone. Other high-technology economies with a high ratio of disposable materials (containers, packaging) face the same problems.

Disposal of these wastes is a major worldwide problem. The growing volume of waste must be put somewhere, but space for it is no longer easy to find. In poorer countries waste is thrown onto open dumps where vermin multiply, decomposition sends methane gas into the air, rain and waste liquids carry contaminants into the groundwater below, and fires pollute the surrounding atmosphere. In countries that can afford it, such open dumps have been replaced by **sanitary landfills**. The waste is put in a hole that has been dug and prepared for the purpose, including a floor of materials to treat seeping liquids and soil to cover each load as it is compacted and deposited in the fill.

The number of suitable sites for sanitary landfills is decreasing, however, and it is increasingly difficult to design new sites. In the United States landfill capacity has been reached or will soon be reached in about a dozen States, most of them in the Northeast and Mid-Atlantic regions, and those States must now buy space from other States for this purpose. Trucking or sending garbage by rail to distant landfills is very expensive, but there are few alternatives.

Similar problems arise on a global scale. The United States, the European Union, and Japan export solid (including hazardous) wastes to countries in Africa, Middle and South America, and East Asia. While these countries are paid for accepting the waste, they do not always have the capacity to treat it properly. So the waste often is dumped in open landfills, where it creates the very hazards that the exporters want to avoid. In the late 1980s, the richer countries' practice of "managing" waste by exporting it became a controversial issue, and in 1989 a treaty was drawn up to control it. The treaty did not (as many poorer countries wished) prohibit the exporting of hazardous waste, although it did place some restrictions on trade in hazardons materials.

It is useful to differentiate between **toxic wastes**, in which the danger is caused by chemicals, infectious materials, and the like, and **radioactive wastes**, which are of two types: low-level radioactive wastes, which give off small amounts of radiation and are produced by industry, hospitals, research facilities, and nuclear power plants; and high-level radioactive wastes, which emit strong radiation and are produced by nuclear power plants and nuclear weapons factories. In the United States, low-level radioactive wastes have for many years been disposed of in steel drums placed in six special government-run landfills, three of which are now closed.

High-level radioactive waste is extremely dangerous and difficult to get rid of. Fuel rods from nuclear reactors will remain radioactive for thousands of years and must be stored in remote places where they will not contaminate water, air, or any other part of the environment. In fact, no satisfactory means or place for the disposal of high-level radioactive waste has been found. Among many suggested disposal sites are deep shafts in the bedrock, chambers dug in salt deposits (salt effectively blocks radiation), ice chambers in Antarctica, sediments beneath the ocean floor, and volcanically active midocean trenches. Meanwhile, spent fuel rods (which last only about three years in the reactor) are put in specially designed drums and stored in one of about 100 sites, all of them potentially dangerous. In the early 2000s the U.S. government developed two major disposal sites—one at Yucca Mountain in southern Nevada, for waste from commercial nuclear power plants, and the other near Carlsbad in southern New Mexico, for military waste.

There is a related problem: transportation of waste. Even if secure and safe storage can be found for high-level radioactive waste, the waste has to be transported from its source to the disposal site. Such transportation presents an additional hazard; a truck or train accident could have disastrous consequences.

The dimensions of the waste-disposal problem are growing and globalizing. The threat to the planet's environment is not just over the short term but can exist for centuries, indeed millennia.

Biodiversity

A significant change that is related to all of the developments discussed so far is the accelerating loss of **biodiversity**. An abbreviation of "biological diversity," biodiversity refers to the diversity of all aspects of life found on the Earth. Although the term is commonly used when referring to the diversity of species, it encompasses the entire range of biological diversity, from the genetic variability within individuals of a species to the diversity of ecosystems on the planet.

How many species are there? Estimates range from 10 million to 100 million, and no one is quite sure how many. So far only some 1.75 million species have been identified, and new species, particularly new species of insects, are being discovered regularly. Yet species are also becoming extinct at a rapid rate. It is difficult to say exactly how quickly extinctions are occurring, since we do not know how many species there are. What is clear, however, is that although extinction is a natural process, humans have dramatically increased rates of extinction, particularly over the last few hundred years. Estimates from the United Nations Environment Program's Global Biodiversity Assessment indicate that 8 percent of plants, 5 percent of fish, 11 percent of birds, and 18 percent of the world's mammal species are currently threatened.

Where is biodiversity most threatened? Whether a species is threatened with extinction depends on the range of the species, its scarcity, and its geographic concentration. If a species with a small range, a high degree of scarcity, and a small geographic concentration has its habitat threatened, extinction can follow. Because most species have small ranges, change in a small area can affect a species. A 2005 report in *Scientific American* explained that "Clearing a forest, draining a wetland, damming a river or dynamiting a coral reef to kill its fish can more readily eliminate species with small ranges than more widespread species."

Human impacts on biodiversity have increased over time. The domestication of animals, followed by the agricultural domestication of plant life, caused significant changes in our relationship with other species. Large vertebrates have always been particularly hard hit by human activities. Many birds and mammals have been hunted not only for food but also for their skins, feathers, and so forth. During the eighteenth and nineteenth centuries, beaver populations in North America were drastically reduced as the beavers were trapped and skinned for their pelts; many bird species were hunted for their feathers, which were sold to decorate fashionable hats. Elephants and walruses continue to be hunted for their ivory tusks. From historical records we know that over 650 species of plants and over 480 animal species have become extinct in just the last 400 years. These represent only the documented extinctions. The actual number of extinctions that occurred during this period is almost certainly much higher.

Humans have also indirectly contributed to extinctions. Human travel, for instance, introduced new species to areas around the globe—rats are among the more destructive of these; they have had devastating effects on oceanic islands. Introduced species may cause extinctions by preying upon native species or competing with them for resources. A famous example is the dodo bird (*Raphus cuculatus*), which was hunted to extinction by humans, dogs, and rats on the island of Mauritius. Introduced species may also carry new diseases, leading to the decimation and extinction of local populations. Species on islands are particularly susceptible to extinction because of the more insular ecosystems found on islands. An estimated 2000 species of birds on tropical Pacific Islands became extinct following human settlement.

Identifying the nature and extent of environmental changes is only a first step toward understanding the extent of human alteration of the planet. A second, and more complicated step is to consider the forces driving these changes.

thinking geographically

What is the greatest environmental concern facing the region where you live, and in what other regions of the world is this a major concern?