WHAT ARE THE MAJOR FACTORS CONTRIBUTING TO ENVIRONMENTAL CHANGE TODAY?

Global environmental changes express themselves at all scales, from local to global. For example, deforestation can have a local effect by reducing the diversity of species in a particular area. It can have regional impacts by increasing sediment runoff into rivers. Finally, at a global scale, deforestation is associated with the release of carbon dioxide into the atmosphere and may affect global climate by altering processes that occur at the land surface. To fully understand deforestation, we must keep all of these scales in mind.

Several interrelated factors are responsible for the expanding impact of humans on the environment over the past two centuries. One of these factors is the dramatic growth of the human population. Even considering the minimal needs for human survival, there can be little doubt that the fourfold increase in the human population in the twentieth century had significant environmental impacts. Another factor is consumption, which has increased dramatically in the modern world. Yet another is technology, which has both expanded the human capacity to alter the environment and brought with it increasing energy demands. Each of these interrelated factors that contribute to environmental change can be studied broadly, focusing on the general impacts of each factor on the global environment. Yet, when we shift scales to the local and regional, and we consider the context of human actions at these scales, we often find that the causes of environmental change vary depending on the local and regional context.

Political Ecology

Leslie Gray and William Moseley describe the field of political ecology, beginning in the 1960s and 1970s, as a way of considering the roles of "political economy, power and history in shaping human-environmental interactions." Political ecologists use scale to consider how attempts to affect environmental change, such as deforestation, differ across scales. Following an environmental problem from its location of outcome (e.g., a cleared patch of forest) backward to the "cause" of the problem is made difficult due to the many players, scales, and power relationships involved. In concerning ourselves only with the global scale, we miss the local. As Gray and Moseley observe, "The spatial distribution of environmental degradation and resource access is unequal both within localities and globally".

At the local scale, Moseley has studied the conservation behaviors of farmers in southern Mali (Fig 13.13). He found that one view that is widely held at the global scale—that poorer people degrade the land more than wealthier people—was not true at the local scale. In fact, through extensive fieldwork, interviews, and soil surveying, moseley, found that poorer farmers in southern Mali were more likely to use organic materials to preserve topsoil and that wealthier farmers were more likely to use inorganic fertilizers and pesticides. Aside from being able to afford inorganic fertilizers, wealthier farmers did so in order to produce cotton more easily. Policies and power relationships at the local, national, and global scales help explain why wealthier farmers in southern Mali produce cotton. For example, the government of Mali's agricultural extension service singled out the wealthiest households for cotton farming, which "helped these households become even wealthier in the short term."

Population

Because humans across the world do not consume or pollute in exactly the same ways, we cannot make a simple chart showing that each additional human born on Earth results in a certain amount of consumption or pollution. We can, however, recognize that humans impact the environment and that a greater number of people on Earth translates into a greater capacity for environmental change.

Similarly, environmental change impacts humans differently, depending in part on who they are and where they live. To underscore the spatial differences in environmental impact on humans, we can consider two maps of natural disaster hot spots published by the Earth Institute at Columbia University and the World Bank in a 2005 report. The maps highlight the places in the world most susceptible to natural disasters, whether caused by drought, tectonic activity (earthquakes and volcanoes), or hydrological hazards (floods, cyclones, and landslides) (Fig. 13.14). Comparing the map of mortality risk with the map of total economic loss risk demonstrates that when a natural disaster hits a wealthier area of the world, the place will more likely be hit financially, whereas, in a poorer area of the world, the place will likely be hit by both financial loss and the loss of lives.

To understand better the differences in mortality and financial risks shown on these maps, we need to focus attention on the spatial differences in human impacts on environment. A clear difference emerges when we consider varying spatial patterns of consumption, transportation, and energy use in the world.

Patterns of Consumption

Humans rely on the Earth's resources for our very survival. At the most basic level, we consume water, oxygen, and organic and mineral materials. Over time we have

Guest Field Note

Try, Mali

In this photo, a young man brings home the cotton harvest in the village of Try in southern Mali. Prior to my graduate studies in geography, I spent a number of years as an international development worker concerned with tropical agriculture—both on the ground in Africa and as a policy wonk in Washington, D.C. I drew at least two important lessons from these experiences. First, well intentioned work at the grassroots level would always be limited if it were not supported by broader scale policies and economics. Second, the people making the policies were often out of touch with the real impacts their decisions were having in the field. As such, geography, and the subfield of political ecology, were appealing to me because of its explicit attention to processes operating at multiple scales, its tradition of fieldwork, and its long, standing attention to human–environment interactions. I employed a political ecology approach during fieldwork for my dissertation in 1999–2000. Here, I sought to test the notion that poor farmers are more likely to degrade soils than their wealthier counterparts (a concept widely proclaimed in the development policy literature of the 1990s). Not only did I interview rich and poor farmers about their management practices, but I tested their soils and questioned policymakers at the provincial, national, and international levels. My findings (and those of others) have led to a questioning of the poverty-environmental degradation paradigm.

Credit: William Moseley, Macalester College

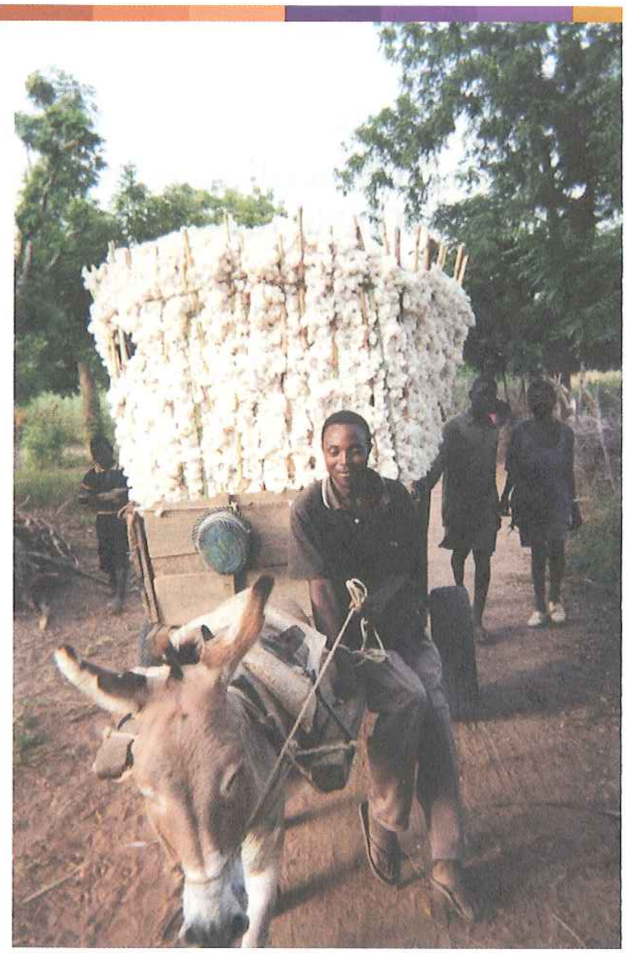


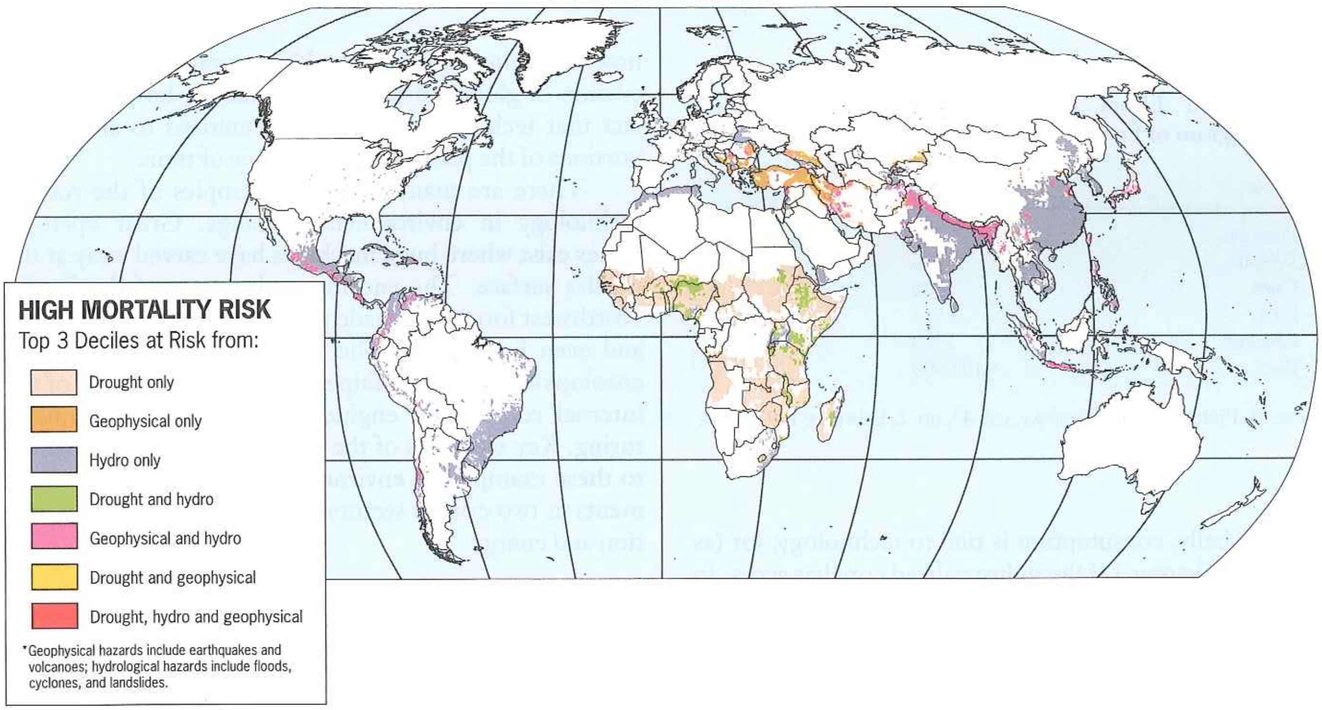
Figure 13.13
Try, Mali

developed increasingly complex ways of using resources by such means as intensive agriculture and industrial production. Consequently, many societies now consume resources at a level and rate that far exceed basic subsistence needs. In a 1996 article on "Humanity's Resources" in *The Companion Encyclopedia of Geography: The Environment and Humankind*, I. G. Simmons notes that a hunter-gatherer could subsist on the resources found within an area of about 26 square kilometers, whereas today many people living in urban centers in the global economic core have access to resources from all over the planet.

Generally, the smaller numbers of people in the core parts of the world make far greater demands on the Earth's resources than do the much larger numbers in the poorer countries. It has been estimated that a baby born in the United States during the first decade of the twenty-first century, at current rates, consumes about 250 times as much energy over a lifetime as a baby born in Bangladesh over the same lifetime. In terms of food, housing, and its components, metals, paper (and thus trees), and many other materials, the consumption of individuals in affluent countries far exceeds that of people in poorer countries. Thus, rapid population growth in the periphery tends to have local or regional environmental impacts. Population growth in the core is also a matter of concern, one whose impact is not just local or regional but global.

All of this underscores the importance of thinking geographically about human impacts on the natural world. People living in the global economic periphery tend to affect their immediate environment, putting pressure on soil, natural vegetation, and water supplies, and polluting the local air with the smoke from their fires. The reach of affluent societies is much greater. The demand for low-cost meat for hamburgers in the United States has led to deforestation in Central and South America to make way for pastures and cattle herds. This, in turn, has greatly increased water demand in such areas (Table 13.1). Thus, the American (and European, Japanese, and Australian) consumer has an impact on distant environments.

MORTALITY RISKS



ECONOMIC LOSS RISKS

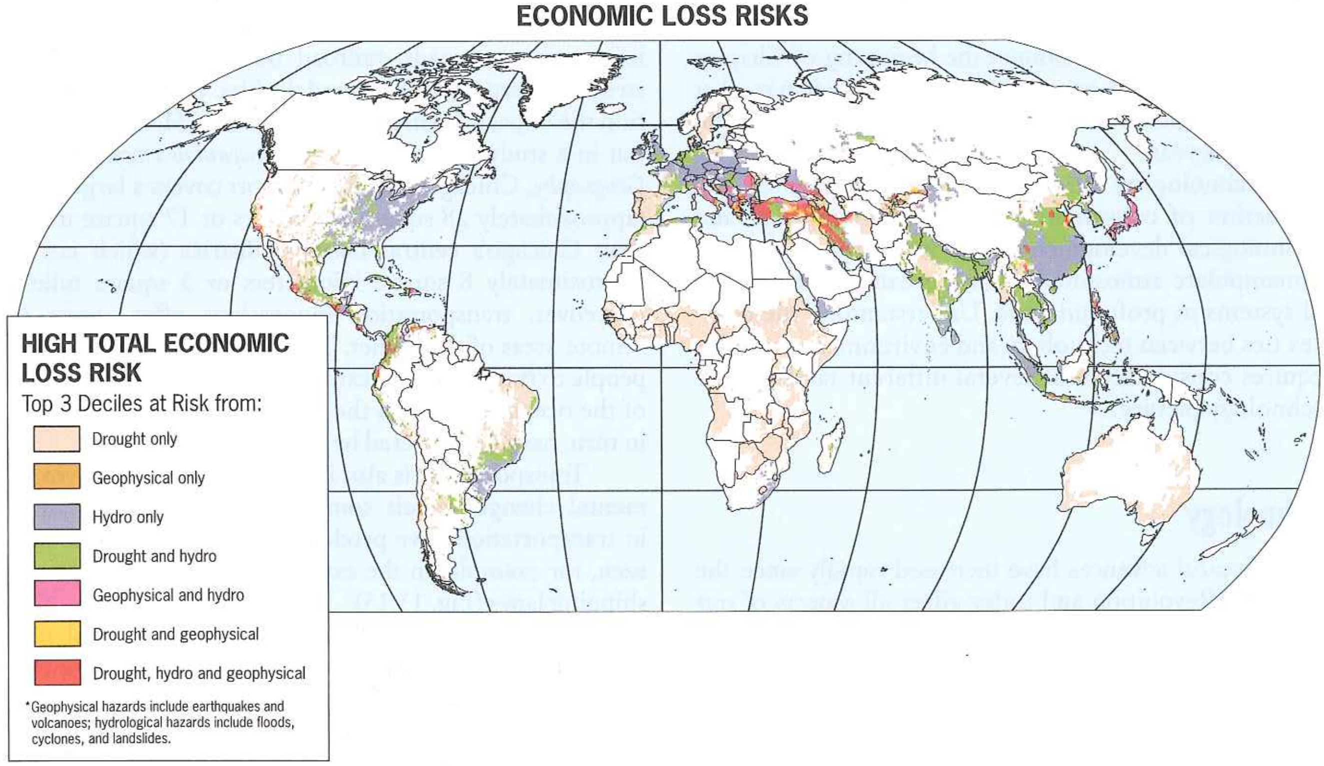


Figure 13.14

Natural Disaster Hot Spots. The top map shows the potential mortality risks if major natural disasters occur in global natural disaster hot spots, and the bottom map shows the potential economic risks if major natural disasters occur in natural disaster hot spots. *Courtesy of:* Center for Hazards and Risk Research at Columbia University and the World Bank, "Natural Disaster Hotspots—A Global Risk Analysis," March 29, 2005.

TABLE 13.1
Estimated Liters of Water Required to Produce 1 Kilogram of Food

Crop	Liters/Kg
Potatoes	500
Wheat	900
Corn	1400
Rice	1912
Chicken	3500
Beef	100,000

Source: D. Pimentel et al., *Bioscience*, vol. 47, no. 2, February 1997, p. 98.

Globally, consumption is tied to technology, for (as we saw in Chapter 12) the industrialized core has access to a vast array of transportation and communication technologies that allow advertisers to stimulate demand for particular goods around the world and allow manufacturers to bring those goods from distant places. The growth of wealth over the last ten years in the semiperiphery, including India and China, and their growing middle and upper classes, have increased the global consumption of consumer goods. For example, in 2008, the Indian company Tata (which we talked about at the beginning of Chapter 4) created the Nano, an automobile for the Indian market that is priced below $2500. Tata plans to produce 250,000 Nano cars a year.

Technological developments have expanded the production of consumer goods for consumption, and technological developments have also allowed humans to manipulate atmospheric, land, oceanic, and biological systems in profound ways. Understanding the complex ties between technology and environmental change requires consideration of several different facets of the technology picture.

Technology

Technological advances have increased rapidly since the Industrial Revolution and today affect all aspects of our lives. We are continually developing technologies that we hope will improve our standard of living, protect us against disease, and allow us to work more efficiently. These technologies have not come without a cost. Resource extraction practices such as mining and logging, which provide the materials to produce technologies, have created severe environmental problems. Energy is required not only to develop new technologies but to use them as well; fossil fuel consumption has contributed to many types of pollution and is a factor in climate change. Technological innovations have produced hazardous and toxic by-products, creating pollution and health problems that we are only now beginning to recognize. Most significant for our discussion of global environmental change, however, is the fact that technology has enabled humans to alter large portions of the planet in a short space of time.

There are many dramatic examples of the role of technology in environmental change. Great open-pit mines exist where huge machines have carved away at the Earth's surface. The enormous clear-cuts of the Pacific Northwest forests are made possible by chainsaws, trucks, and even helicopters. The heavy blanket of smog that envelops cities such as Taipei (Taiwan) is a product of the internal combustion engine and mechanized manufacturing. Key elements of the technologies that contribute to these examples of environmental change are developments in two critical sectors of the economy: transportation and energy.

Transportation

Modes of transportation represent some of the most important technological advances in human history. Each innovation in transportation has required increased resource use, not only to make the vehicles that move people and goods, but also to build and maintain the related infrastructure—roads, railroad tracks, airports, parking structures, repair facilities, and the like. With each innovation the impacts seem to widen. As David Headrick points out in a study discussed in the *Companion Encyclopedia of Geography*, Chicago's O'Hare Airport covers a larger area (approximately 28 square kilometers or 17 square miles) than Chicago's central business district (which covers approximately 8 square kilometers or 5 square miles). Moreover, transportation innovations offer access to remote areas of the planet. There are vehicles that allow people to travel through extreme climates, to the bottoms of the ocean, and across the polar ice caps. These places, in turn, have been altered by human activity.

Transportation is also implicated in global environmental change—albeit sometimes indirectly. Advances in transportation have produced significant pollution, as seen, for example, in the extent of oil spills along major shipping lanes (Fig. 13.15).

Transportation facilitates the types of global networks necessary to sustain the patterns of consumption outlined earlier. Many of the products available in stores—be they electronics or clothing or food—come from distant places. Resources are required to produce and ship them, and except those that meet basic subsistence needs, they all contribute to the greater strains placed on the environment that come from those living in the wealthier parts of the world. This realization has led some individuals to reduce their levels of consumption or to consume more environmentally friendly, locally produced products. These changes have had some effect, but so far their

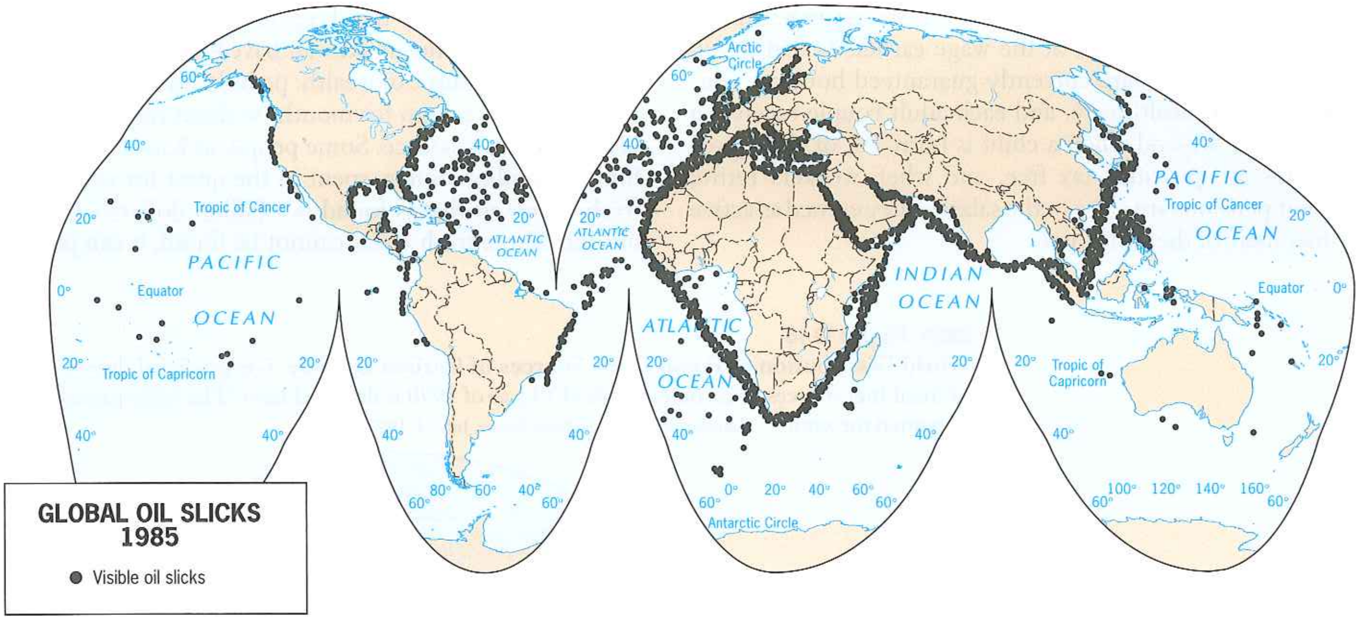


Figure 13.15
Locations of Visible Oil Slicks. Oil slicks are a problem around the globe, as this map shows. *Adapted with permission from:* Organization for Economic Co-operation and Development, *The State of the Environment,* 1985, p. 76.

impact on the geography of global consumption has been marginal.

Energy

Consumption of material goods is closely linked to the consumption of energy. It takes energy to produce material goods, energy to deliver them to markets, and, for many products (such as appliances and automobiles), energy to keep them running. The resulting demands for energy are a factor in environmental change. Much of our energy supply comes from nonrenewable fossil fuels, such as coal, oil, and natural gas. Moreover, the evolution of tertiary, quaternary, and quinary economic activities has not reduced the consumption of nonrenewable resources. As populations grow, so does the demand for energy, and we can expect that over the coming decades energy production will expand to meet the increased demand. In developing countries in particular, demands for more energy are met by increasing the development of fossilfuel sources. This helps explain why, according to the United States Energy Information Administration, global oil production increased from 45.89 million barrels per day in 1970 to 73.27 million barrels per day in 2007.

Oil is a finite resource. It is not a question of *if* the world's oil supply will run out but *when*. Because discoveries of new reserves continue to be made, and because the extraction of fossil fuels is becoming ever more efficient, it is difficult to predict exactly how much longer oil will remain a viable energy source. Many suggest that the current level of oil consumption can be sustained for up to 100 years, although some argue for much shorter or much longer time frames. Despite the range of opinion, the majority of scientists believe that, by the middle of this century, alternative sources will have to be developed.

When one considers that oil could become an increasingly scarce commodity within the lifetimes of many college students today, the importance of finding alternative energy sources becomes apparent. Adding further urgency to the quest are the pollution problems associated with the burning of fossil fuels and the geopolitical tensions that arise from global dependence on a resource concentrated in one part of the world. Moving away from a dependence on oil carries with it some clear positives, but it could lead to wrenching socioeconomic adjustments as well.

The effects of a shift away from oil will certainly be felt to some degree in the industrial and postindustrial countries, where considerable retooling of the economic infrastructure will be necessary. It is the oil-producing countries, however, that will face the greatest adjustments. More than half of the world's oil supply is found in the Middle Eastern countries of Saudi Arabia, Iraq, Kuwait, the United Arab Emirates (UAE), and Iran. In each of these countries, the extraction and exportation of oil account for at least 75 percent of total revenue and 90 percent of export-generated income. What will happen to these countries when their oil reserves run dry?

Consider the case of Kuwait—a country in which the incomes of 80 percent of the wage earners is tied to oil. Kuwait's citizens are currently guaranteed housing, education, and health care, and each adult couple receives a one-time stipend when a child is born. All of these programs are provided tax free, and when workers retire, their pensions are close to the salaries they earned as active members of the workforce.

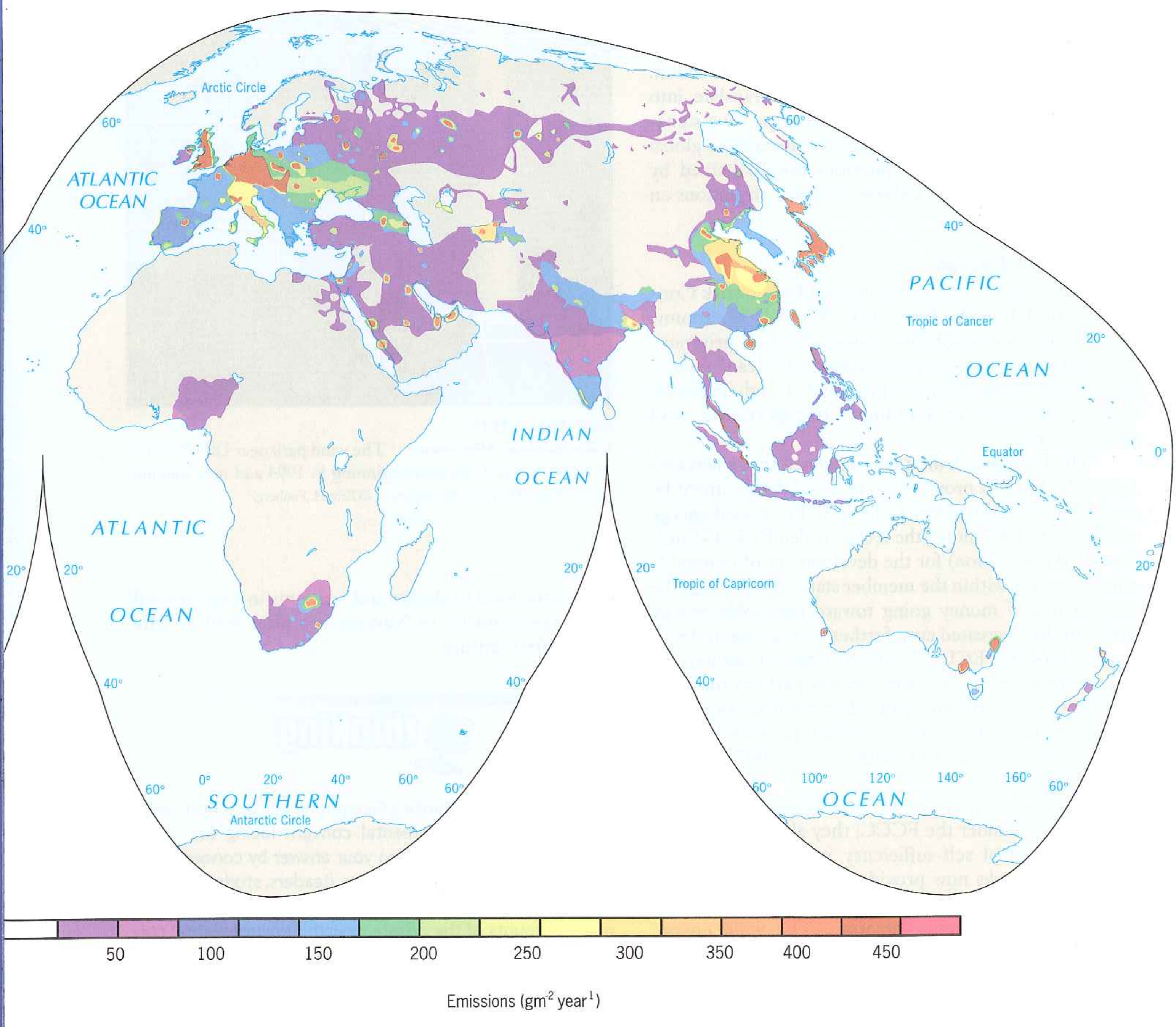
Concerns over the long-term implications of a decline in oil revenue in Kuwait have led to efforts to find an alternative source of wealth: potable water. In a part of the world that can go for months without rain, water is a most precious resource. Some people in Kuwait joke that for each million dollars spent in the quest for sources of fresh water, all that is found is a billion dollars worth of oil! But where fresh water cannot be found, it can poten-

Figure 13.16

World Distribution of Fossil Fuels Sources of Carbon Dioxide. Geographical distribution of fossil fuel sources of carbon dioxide (CO_2) as of 1990 is depicted here. The basic pattern has remained the same. *Adapted with permission from: Science*, July 25, 1997.

tially be made, and Kuwait has begun to position itself to become one of the world's leaders in the field of desalinization (the conversion of saltwater to fresh water). This is currently a very expensive process, but Kuwait is able to devote some of its oil revenues to research and development on the desalinization process. Absent a major technological breakthrough, in the short term income generated by desalinization will amount to only a tiny fraction of the income provided by oil production. The long term may be a different story, however. If not, Kuwait—and other countries in its position—will be facing a socioeconomic adjustment of enormous proportions.

If we look at the global distribution of fossil fuel sources of CO_2 (Fig. 13.16), we can see that production is concentrated in the highly industrialized part of the global economic core. Pollution associated with this



energy production creates acid rain. The damming of rivers for hydropower alters fresh water systems. Nuclear power is being experimented with throughout the world, but the highly volatile byproducts of this form of energy production and the potential for accidents have limited the expansion of nuclear energy.

Technology has played a key role in amplifying human-induced environmental change. At the same time, technologies are being developed to identify and solve environmental problems. Some of these offer alternative approaches to local energy production.

The growing number of international environmental agreements signed in recent years reflects mounting international concern over the state of the global environment. The scope of these international agreements is primarily global in the sense that members of the international community agree to a global blueprint for action. How do these international agreements translate into regional or local action? What actual steps have signatory countries taken in their attempts to meet these global goals? Insights into these questions can be gained by looking at regional and local responses to conventions on climate change.

Alternative Energy

Since the United Nations-sponsored Framework Convention on Climate Change (FCCC) in 1992, a number of countries established implementation programs that encourage both the development of "clean" renewable energy technologies (Fig. 13.17) and increased energy efficiency in buildings, transportation, and manufacturing.

The European Union has mandated that a percentage of the funds it provides for regional development be used for renewable energy projects and increased energy efficiency. In 1994 alone, the EU provided ECU 175 million (US$159 million) for the development of renewable energy sources within the member states. Since 1994, the amount of EU money going toward renewable energy programs has increased even further. In one case, in 1997, the EU provided ECU 43 million (US$39.1 million) for the construction of three wind energy parks in the State of Navarra in northern Spain. The wind energy parks in Navarra and other regions of Spain generated a 9120 GWh (gigawatt hours) of electricity in 2002, creating €695 million in income.

These wind energy parks not only help the EU meet its obligations under the FCCC; they also help Navarra achieve a goal of self-sufficiency in energy. Navarra's wind energy parks now provide over 50 percent of the region's electric energy needs. More has changed in Navarra than its energy situation. The wind energy parks, located in the Guerinda Mountains 30 kilometers (18.6 miles) southeast of the city of Pamplona have altered the local landscape and economy in ways that will shape the character of Navarra as a place well into the twenty-first century.

Figure 13.17
Lake Benton, Minnesota. The wind park near Lake Benton, Minnesota was developed beginning in 1994 and now includes more than 200 wind turbines. © Erin H. Fouberg.

thinking geographically

Go back to the last Thinking Geographically question—what is the greatest environmental concern facing the region where you live? Now, add to your answer by concentrating on how people in the community (leaders, students, locals, businesses) discuss this environmental concern. Read newspaper accounts of the debate over this environmental concern. Are the actors in this debate thinking and operating at different scales?

HOW ARE HUMANS RESPONDING TO ENVIRONMENTAL CHANGE?

Technology is only one part of the picture of the human response to environmental change. The extent and rapidity of that change have led to numerous policies aimed at protecting the environment or reversing the negative impacts of pollution. These policies range from local ordinances that restrict urban development in environmentally sensitive areas to global accords on topics such as biodiversity and climate change.

A major challenge in confronting environmental problems is that many of those problems do not lie within a single jurisdiction. Many environmental problems cross political boundaries, and people sometimes move across those boundaries in response to environmental pressures. Designing policy responses is thus complicated by the fact that the political map does not reflect the geography of environmental issues. The problem is particularly acute when environmental problems cross international boundaries, for there are few international policymaking bodies with significant authority over multinational environmental spaces. Moreover, those that do exist—the European Union, for example—often have limited authority and must heed the concerns of member states. Those concerns, in turn, may not coincide with the interests of the environment. Within democracies, politicians with an eye to the next election may hesitate to tackle long-term problems that require short-term sacrifices. Most authoritarian regimes have an even worse record, as can be seen in the policies of the Soviet-dominated governments of Eastern Europe during the communist era. Moreover, governmental leaders in peripheral countries find it very difficult to take action when, as is often the case, action requires reductions in already marginal standards of living and even greater difficulties in meeting the kinds of debt payments discussed in Chapter 10.

Despite these obstacles, the growing extent and urgency of global environmental changes have led to a number of international agreements to address some of the most severe problems. Some of these have been spearheaded by nongovernmental organizations (NGOs) that operate outside of the formal political arena. They tend to focus on specific issues and problems, often in particular places. With the 1972 *United Nations Conference on the Human Environment* in Stockholm, international governmental organizations began playing a major role in environmental policy.

The framework that currently guides international governmental activity in the environmental arena evolved from the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992. The delegates to UNCED gave the Global Environment Facility (GEF)—a joint project of the United Nations and the World Bank—significant authority over environmental action on a global scale. The GEF funds projects related to six issues: loss of biodiversity, climate change, protection of international waters, depletion of the ozone layer, land degradation, and persistent organic pollutants. The delegates to UNCED believed that significant progress could be made through these funded projects, along with bilateral (that is, government-to-government) aid. They also made it easier for NGOs to participate in international environmental policymaking.

These actions hold the promise of a more coherent approach to environmental problem solving than is possible when decisions are made on a state-by-state basis. Yet individual states continue to influence decision making in all sorts of ways. Take the case of the GEF. Even though the GEF is charged with protecting key elements of the global environment, it still functions in a state-based world, as suggested by Figure 13.18—a map from a 1994 World Bank technical report on the forest sector in Subsaharan Africa that divides the realm into "major regions" that cut across forest zones. In addition to often limiting its perceptions of environmental issues to state boundaries, the GEF depends on states for funding projects. Between 1991 and 2004, the GEF provided $4.5 billion in grants. Although the GEF is often limited by state boundaries, it nonetheless serves the important role of providing financial resources to four major international conventions on the environment: the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification, and the Stockholm Convention on Persistent Organic Pollutants.

A few global environmental issues are so pressing that efforts are being made to draw up guidelines for action in the form of international conventions or treaties. The most prominent examples are in the areas of biological diversity, protection of the ozone layer, and global climate change.

Biological Diversity

International concern over the loss of species led to calls for a global convention (agreement) as early as 1981. By the beginning of the 1990s, a group working under the auspices of the United Nations Environment Program reached agreement on the wording of the convention, and it was submitted to UNCED for approval. It went into effect in late 1993; by 2001, 168 countries had signed it. The convention calls for the establishment of a system of protected areas and for a coordinated set of national and international regulations on activities that can have significant negative impacts on biodiversity. It also provides

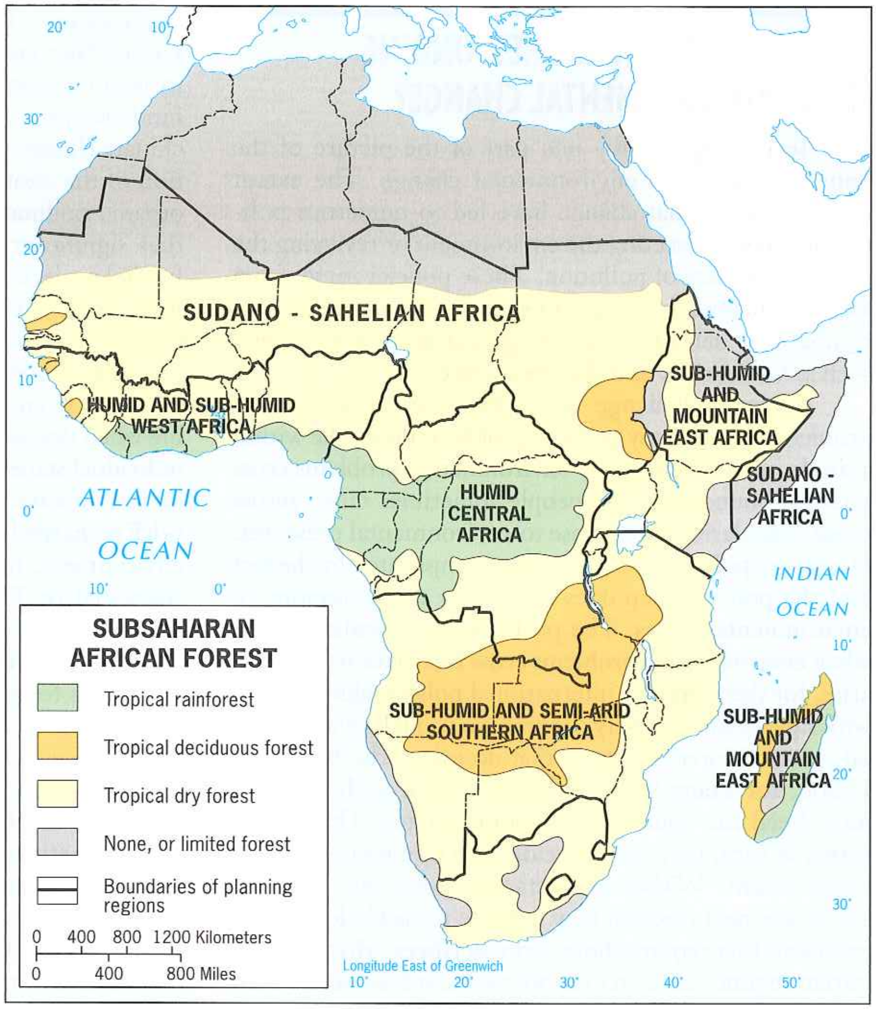


Figure 13.18
Major Regions and Forest Zones in Subsaharan Africa. This map is based on a figure in a World Bank technical paper on the forest sector in Subsaharan Africa. The map shows major forest regions crossing state boundaries, but planning regions adhere to state boundaries. *Adapted with permission from:* N. P. Sharma, S. Rietbergen, C. R. Heimo, and J. Patel. A Strategy for the Forest Sector in Sub-Saharan Africa, World Bank Technical Paper No. 251, Africa Technical Department Series (Washington, D.C.: The World Bank, 1994).

funding for developing countries that are trying to meet the terms of the convention.

The biodiversity convention is a step forward in that it both affirms the vital significance of preserving biological diversity and provides a framework for cooperation toward that end. However, the agreement has proved difficult to implement. In particular, there is an ongoing struggle to find a balance between the need of poorer countries to promote local economic development and the need to preserve biodiversity, which happens to be richest in parts of the global economic periphery. Also, there has been controversy over the sharing of costs for conservation programs, which has led to heated debates over ratification of the convention in some countries. Nevertheless, this convention, along with a host of voluntary efforts, has helped to focus attention on the biodiversity issue and to promote the expansion of protected areas. Whether those areas will succeed in providing long-term species protection is an open question that will occupy geographers and biologists for years to come.

Protection of the Ozone Layer

When found in the troposphere (0 to 16 kilometer or 1.0 to 10 mile altitude), ozone (O_3) gas is a harmful pollutant closely associated with the creation of smog. However, a naturally occurring **ozone layer** exists in the upper levels of the stratosphere (between 30 and 45 kilometer altitude). The ozone layer is of vital importance, because since it protects the Earth's surface from the sun's harmful ultraviolet rays. In 1985, a group of British scientists working in Antarctica discovered that the thickness of the ozone layer above the South Pole had been dramatically reduced, from 300 Dobson units (DUs) in the 1960s to almost 200 DUs by 1985. Studies revealed that the main culprits in ozone depletion were a group of human-made gases collectively known as CFCs (chlorofluorocarbons). These gases, used mainly as refrigerants in fire extinguishers and in aerosol cans, had only been in use since the 1950s and were thought to be completely harmless to humans. The strength of the scientific evidence pointing to a rapid reduction of the ozone layer led to an unusually rapid and united international response.

International cooperation began in 1985 with the negotiation of the **Vienna Convention for the Protection of the Ozone Layer**. Specific targets and timetables for the phase-out of production and consumption of CFCs were defined and agreed upon as part of the international agreement known as the **Montreal Protocol**, which was signed in September 1987 by 105 countries and the European Community. The original agreement called for a 50 percent reduction in the production and consumption of CFCs by 1999. At a meeting in London in 1990, scientific data showing that ozone depletion would continue for many years after a phase-out of CFCs led the signators of the Montreal Protocol to agree to halt CFC production entirely by the year 2000. Finally, at a meeting in Copenhagen in 1992, the timetable for CFC phaseout was accelerated; participants agreed to eliminate CFC production by 1996 and to accelerate the phaseout of other ozone-depleting chemicals such as halons, hydrochlorofluorocarbons, carbon tetrachloride, methyl chloroform, and methyl bromide. This response is an encouraging example of international cooperation in the face of a significant, albeit clearly defined, problem. Unfortunately, the long residence time of CFCs in the atmosphere will mean that their effects will be felt for a long time to come.

Global Climate Change

Beginning in the late 1980s, growing concern about climate change led to a series of intergovernmental conferences on the nature and extent of human impacts on the climate system. The second of these conferences, held in Geneva in 1990, was sponsored by the World Meteorological Organization, the United Nations Environment Program, and other international organizations. It brought together representatives from 137 states and the European Community. The delegates concluded that there was enough evidence of human impacts on climate to justify efforts to draw up a treaty on climate change. The final declaration, adopted after hard bargaining, did not specify any international targets for reducing emissions. Instead, it proclaimed climate change as a "common concern of humankind," while noting that "common but differentiated responsibilities" existed between the industrialized core and the less industrialized periphery.

In December 1990, the United Nations General Assembly approved the start of treaty negotiations. A draft convention was prepared and submitted to UNCED for consideration. The convention was presented in general terms, but it called on the developed countries to take measures aimed at reducing their emissions to 1990 levels by the year 2000 and to provide technical and financial support for emission-reduction efforts in the developing countries. The convention was signed by 154 states and the European Community in Rio de Janeiro.

For several years after UNCED, various committees met to discuss matters relating to the convention. By 1995, mounting concerns about the nature of long-term commitments under the convention led the participants in these discussions to call for a revised treaty that would cover the post–2000 period. They appointed a group to draft an agreement to be considered at a 1997 meeting in Kyoto, Japan. Different proposals were made in the months before this meeting, including one by the Association of Small Island States for a 20 percent cut in CO_2 by the year 2005 and one by the European Union for cuts of 7.5 percent by 2005 and 15 percent by 2010. The United States, however, was concerned about the economic effects of such cuts and the extent to which the burden of reducing emissions fell on the developed countries. It made a more modest proposal to return to 1990 CO_2 levels by 2012 and to reduce CO_2 levels below the 1990 benchmark thereafter.

After ten days of tough negotiations, an agreement was reached that involved compromises for practically every participating country. The agreement set a target period of 2008–2012 for the United States, the European Union, and Japan to cut their greenhouse gas emissions by 7, 8, and 6 percent, respectively, below 1990 levels. In addition, the agreement reached in Kyoto did not obligate less developed countries to adhere to specific reduction goals; instead it called for voluntary emission reduction plans to be implemented individually by those countries with financial assistance from industrialized countries. These plans have been revisited in successive climate change summits in The Hague (November 2000), Bonn (July 2001), and Marrakech (November 2001). The Hague summit collapsed without any agreement, and a further setback occurred in March 2001 when a new presidential administration in the United States suddenly announced its intention to abandon unilaterally the Kyoto Protocol. The Bonn summit thus opened amidst serious differences among countries, but by the end of the summit countries other than the United States signed a statement calling for the Kyoto Protocol to be salvaged. This paved the way for the Marrakech summit, where most countries agreed to a set of general rules for international implementation of the Kyoto Protocol. Without the participation of the United States, however, the impact of this and future agreements will be limited given that the United

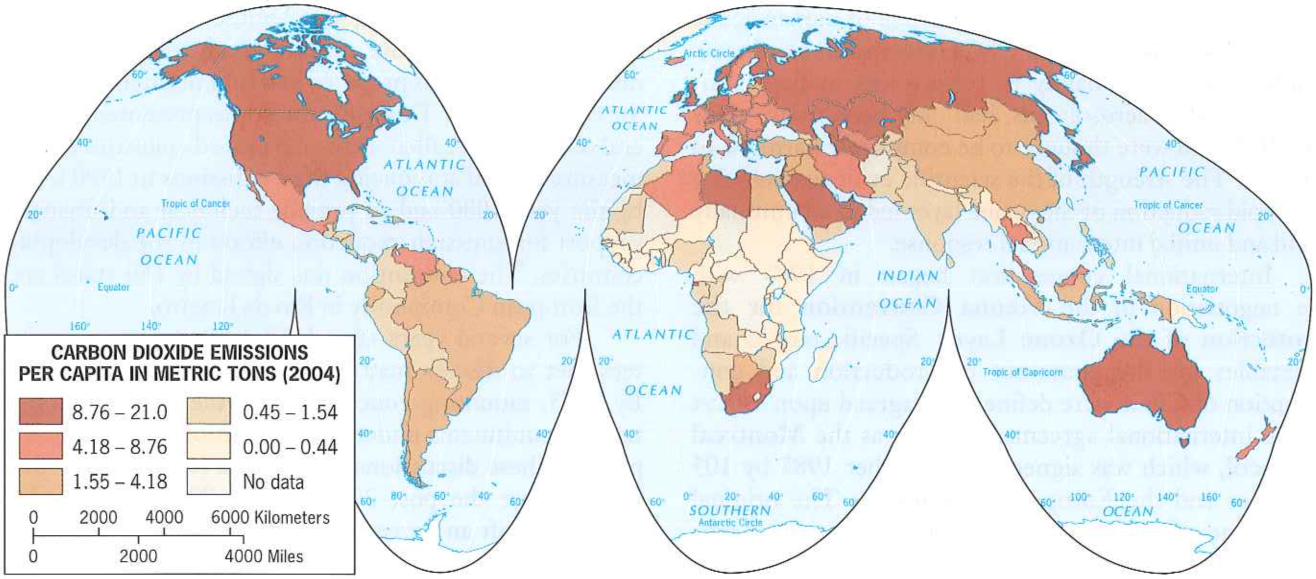


Figure 13.19

Carbon Dioxide Emissions per Capita, 2004. Recently, China's total Carbon Dioxide emissions have increased to the level of the United States. However, in per capita emissions of Carbon Dioxide, mapped here, the US, Canada, and the United Arab Emirates are the highest. *Data from:* United Nations Development Programme, Hum Development Report, 2007/2008.

States produces approximately 24 percent of global CO_2 emissions in 2004.

The United States continues to be the largest producer of carbon dioxide emissions, per person, in the world. The United States emited 19.4 tons of carbon dioxide per capita in 2007, and it was followed by the European Union with 8.6 tons, China with 5.1 tons, and India with 1.8 tons (Fig. 13.19). However, in 2006, China took the lead as the world's single largest total emitter of carbon dioxide, pushing the United States out of the top spot. The Beijing Olympics in 2008 opened the world's eyes to the incredibly high emissions level in China (Fig. 13.20).

Figure 13.20

Beijing, China. Smog covers the traffic on a motorway in the Central Business Districts of Beijing just a few months before the opening of the 2008 Olympics in Beijing. © David G. McIntyre/epa/Corbis.

Neither the United States nor China, the world's two largest emitters of carbon dioxide, signed the Kyoto Protocol, which is slated to expire in 2012. By the end of 2009, the Copenhagen climate change agreement will be established. The pressure is high for the United States to play a role in this agreement and in affected climate change. Ongoing discussions of climate change will invariably concentrate on China.

One way individuals, corporations, and governments are working to abate their carbon output (or carbon footprint) is by purchasing carbon offsets. Corporations, including concert promoters, such as Reverb, which we discussed in Chapter 4, encourage recycling, the consumption of local produce, car pooling, and other practices that help people reduce their carbon footprints. Corporations and individuals also purchase carbon offsets (many are available online), and in turn trees are planted, wind turbines are built, and other carbon-reducing actions take place.

Globally, governments are considering a carbon market through which countries could exchange carbon dioxide emissions for preservation of carbon-absorbing forests. A global carbon market would include countries of the periphery and semiperiphery, and would provide these countries with incentive to maintain their forests, which absorb carbon dioxide, rather than clear them. A global carbon market may also provide countries such as the United States an opportunity to continue to emit carbon dioxide at high rates, simply by paying for the rights to do so.

thinking *geographically*

Examine the map of global carbon dioxide emissions and explain the pattern you see. What other geographic patterns are correlated with those shown in the map?

Summary

What will the future be like? Many would agree with geographer Robert Kates, who foresees a "warmer, more crowded, more connected but more diverse world." As we consider this prospect, we must acknowledge that global environmental changes illustrate the limits of our knowledge of the Earth. Many of today's global environmental changes were not anticipated. Moreover, many global changes are nonlinear, and some are "chaotic" in the sense that future conditions cannot be reliably predicted. Nonlinearity means that small actions in certain situations may result in large impacts and may be more important than larger actions in causing change. Thresholds also exist in many systems, which, once past, are irreversible. This occurs, for example, when the habitat for a species is diminished to the point where the species quickly dies off. Unfortunately, we may not be able to identify these thresholds until we pass them. This leaves open the possibility of "surprises"—unanticipated responses by physical systems.

The complexity and urgency of the environmental challenge will tax the energies of the scientific and policy communities for some time to come. Geography must be an essential part of any serious effort to grapple with these challenges. The major changes that are taking place have different origins and spatial expressions, and each results from a unique combination of physical and social processes. We cannot simply focus on system dynamics and generalized causal relationships. We must also consider emerging patterns of environmental change and the impacts of differences from place to place on the operation of general processes. Geography is not the backdrop to the changes taking place; it is at the very heart of the changes themselves.

Geographic Concepts

- chlorofluorocarbons
- Pangaea
- photosynthesis
- mass depletions
- mass extinctions
- Pacific Ring of Fire
- Pleistocene
- glaciation
- interglaciation
- Wisonconsinian Glaciation
- Holocene
- Little Ice Age
- environmental stress
- renewable resources
- hydrologic cycle
- aquifers
- atmosphere
- global warming
- acid rain
- oxygen cycle
- deforestation
- soil erosion
- solid waste
- sanitary landfills
- toxic waste
- radioactive waste
- biodiversity
- ozone layer
- Vienna Convention for the Protection of the Ozone Layer
- Montreal Protocol

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