17

Land Resources

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California condor (*Gymnogyps californianus*), a species which is resident in Pinnacles National Park.

In 2013, a new U.S. national park was designated: Pinnacles National Park, in the California chaparral habitat. This park brings the total number of national parks in the United States to 59.

Pinnacles National Park is one of few habitats where the native California condor can be reliably seen. This species, once at a population of nine remaining individuals, was removed from the wild, eggs were hatched and reared in captivity, and birds were released to the wild. Many of these birds now live in the volcanic rock formations at Pinnacles. Like some other new national parks (Congaree National Park, in South Carolina, for example), Pinnacles had previously been a national monument. (National monuments are similar to national parks except that they are given less funding and therefore less protection.) Over 400 bee species also make use of the habitat at Pinnacles, many of them solitary. Salamanders, butterflies, toads, and many other birds also make their home at Pinnacles. The park offers visitors such recreational activities as hiking, camping, rock climbing, and caving.

Designating a national park does not happen overnight. Theodore Roosevelt established Pinnacles as a national monument in 1908, because of its caves and unique rock formations. The Civilian Conservation Corps established trails in the area and guided visitors to the caves in the 1930s. The area was designated a national park by President Barack Obama in January 2013.

Congaree National Park, established in 2003, was first designated as a national monument in 1976. Congaree is also an International Biosphere Reserve, one of about 500 international areas of significant ecological importance; this designation by the United Nations Educational, Scientific, and Cultural Organization suggests that the host country for this reserve should make strong efforts to preserve it.

Great Sand Dunes National Park and Preserve in Colorado was formerly a national monument that was redesignated a national park in 2004. The tallest sand dunes in North America are located here, on the eastern side of the San Luis Valley. Some dunes are as tall as 230 m (750 ft) above the valley floor. They formed as rain and wind eroded the surrounding mountains and prevailing winds pushed the eroded sand into dunes. As the winds blow, the dunes continually change shape, but they remain more or less in the same position. For recreation, the park offers nature walks, short tours, hiking, and camping, including limited camping on the dunes themselves.

National parks preserve the land as much as possible so that future generations can appreciate and enjoy the beauty of fast-disappearing natural areas. Though many national parks can be crowded in peak seasons, even a short hike leads visitors to great beauty and solitude in these vast and impressive landscapes.

In Your Own Backyard

What national park is closest to where you live? Check online to find out what activities, species, and landscapes are available there.

Land Use

LEARNING OBJECTIVES

- Name at least four ecosystem services provided by natural areas.
- Describe world land use.

Most of Earth's land area has a low density of humans. These sparsely populated **nonurban** or **rural** lands include forests, grasslands, deserts, and wetlands. Most people living in rural areas have jobs directly connected with natural resources, such as farming or logging. The many **ecosystem services** performed by rural lands enable the majority of humans to live in concentrated urban environments. Maintaining parcels of undisturbed land adjacent to agricultural and urban areas provides vital ecosystem services such as wildlife habitat, flood and erosion control, and groundwater recharge. Undisturbed land breaks down pollutants and recycles wastes. Natural environments provide homes for organisms. One of the best ways to maintain biological diversity and to protect endangered and threatened species is by preserving or restoring the natural areas to which these organisms are adapted. (Table 5.1 summarizes some important ecosystem services.)

Scientists use undisturbed rural lands as a benchmark, or point of reference, to determine the impacts of human activity. Geologists, zoologists, botanists, ecologists, and soil scientists are some of the scientists who use undisturbed rural lands for scientific inquiry. These areas provide ideal settings for educational experiences in science as well as history because they demonstrate the way the land was when humans originally settled here.

Unspoiled natural areas are important for their recreational value, providing places for hiking, camping, swimming, boating, rafting, bird watching, sport hunting, and fishing. Wild areas are important to the human spirit. Forest-covered mountains, rolling prairies, barren deserts, and other undeveloped areas are aesthetically pleasing and also help us recover from the stresses of urban and suburban living. We can escape the tensions of the civilized world by retreating, even temporarily, to the solitude of natural areas.

WORLD LAND USE

The extent of human land use is increasingly having global impacts. Currently, humans use an estimated 4% of the world's total land area for cities and 36% for agriculture—that is, for raising crops and livestock (**Figure 17.1**). Another 30% of the land surface consists of rock, ice, tundra, and desert—areas considered unsuitable for long-term human use. This leaves 30% of the land surface as natural ecosystems, such as forests and oceans, that could potentially be developed for human purposes. As we have discussed, these natural ecosystems provide many valuable ecosystem services important to human survival. Yet urban areas, croplands, and pastures have expanded worldwide in recent decades in response to the need to support human populations.

LAND USE IN THE UNITED STATES

About 55% of the land in the United States is privately owned by citizens, corporations, and nonprofit organizations, and about

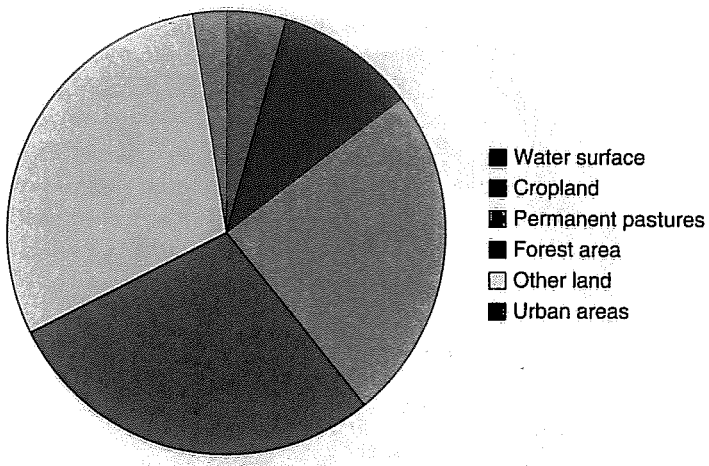


Figure 17.1 World land use. Note that 3.5% of the world's total land is used for cities, and about 36% for agriculture (cropland and pasture land). (WorldStat, Columbia University Socioeconomic Data and Applications Center)

3% by Native American tribes. The rest is owned by the federal government (about 35% of U.S. land) and by state and local governments (about 7% of U.S. land). Government-owned land encompasses all types of ecosystems, from tundra to desert, and includes land that contains important resources such as minerals and fossil fuels, land that possesses historical or cultural significance, and land that provides critical biological habitat. Most federally owned land is in Alaska and 11 western states (**Figure 17.2**). It is managed primarily by four agencies, three in the U.S. Department of the Interior—the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), and the National Park Service (NPS)—and one in the U.S. Department of Agriculture—the U.S. Forest Service (USFS) (**Table 17.1**).

Managing Private Land The American landscape is rapidly changing as it is converted to urban, suburban, and rural residential development. In 2007 the National Resources Inventory of the U.S. Department of Agriculture and the National Resources Conservation Service projected that an area larger than the size of New England could be converted from undeveloped land to residential development by the 2030s. Significant population growth, increasing numbers of retirees, and the consumption of more land per capita are all factors in this projected increase.

Many environmental concerns converge in the matter of land use. Pollution, population issues, preservation of our biological resources, mineral and energy requirements, and production of food are all tied to land use. Economic factors often dominate land use decisions, including the way privately owned land is taxed. Sometimes forest or agricultural land located near urban and suburban areas is taxed as potential urban land. Because of the higher taxes on this land, its owners fall under greater pressure to sell it, which ultimately hastens its development. However, if such land is taxed as forest or farmland, the lower taxes are an incentive for owners to hold onto the land and maintain it in its undeveloped condition. Thus, economic factors largely control land use.

Public Planning of Land Use People in many cities may live surrounded by high-rises and factories or by tree-lined streets

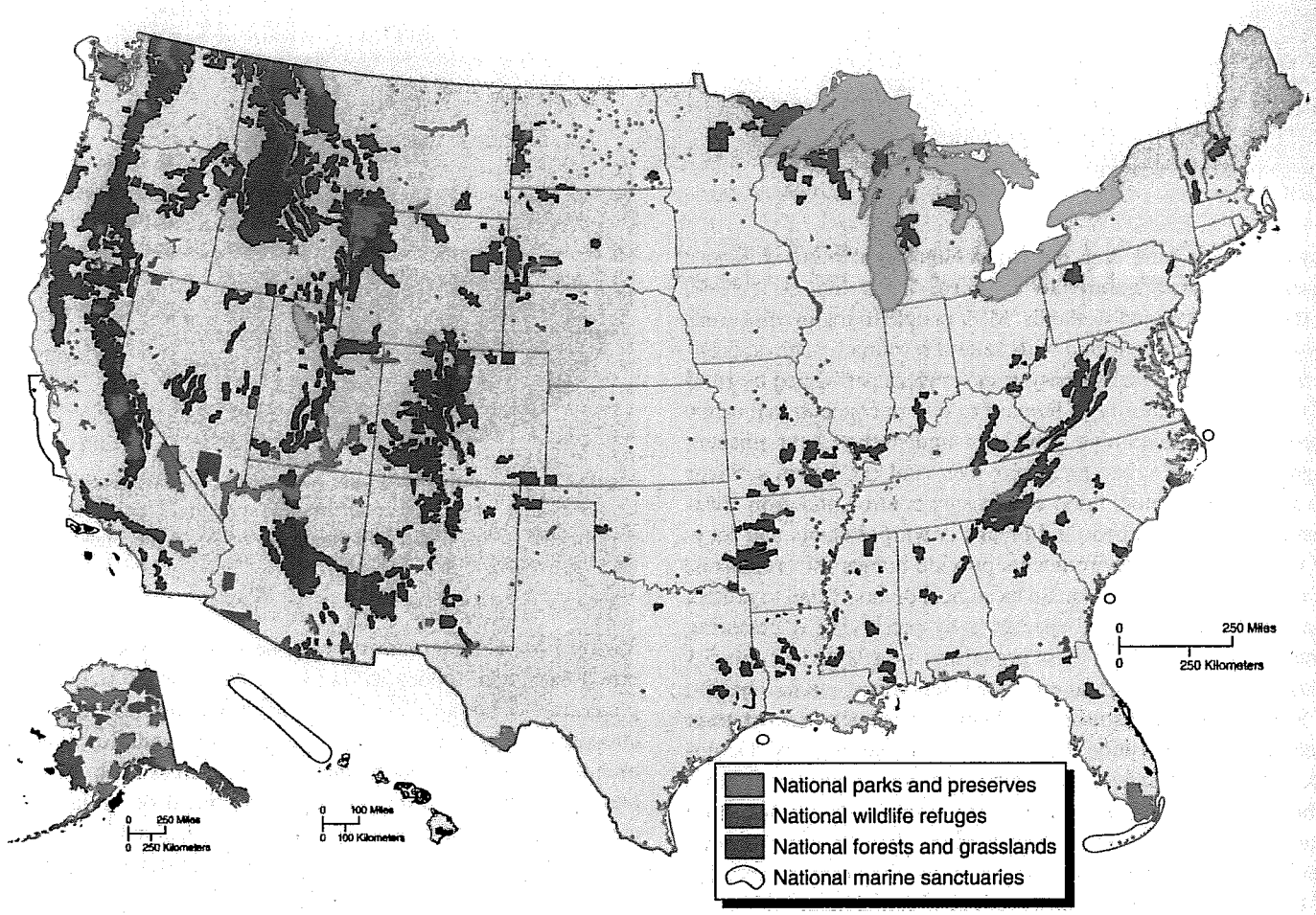


Figure 17.2 Selected federal lands. Shown are national parks and preserves, national wildlife refuges, national forests and grasslands, and national marine sanctuaries in the United States. Note the preponderance of federal lands in western states and Alaska. Other federal lands, such as military installations and research facilities, are not included, though many of these function effectively as wildlife sanctuaries. (National Geographic Maps)

Table 17.1 Administration of Federal Lands

Agency	*Land Held*	*Primary Uses*	*Area in Millions of Hectares (Acres)*
Bureau of Land Management (Dept. of Interior)	National resource lands	Mining, livestock grazing, oil and natural gas extraction	102 (253)
U.S. Forest Service (Dept. of Agriculture)	National forests	Logging, recreation, conservation of watersheds, wildlife habitat, mining, livestock grazing, oil and natural gas extraction	78 (193)
U.S. Fish and Wildlife Service (Dept. of Interior)	National wildlife refuges	Wildlife habitat; also logging, hunting, fishing, mining, livestock grazing, oil and natural gas extraction	38 (93)
National Park Service (Dept. of Interior)	National Park System	Recreation, wildlife habitat	34 (84)
Other—includes Department of Defense, Corps of Engineers (Dept. of the Army), and Bureau of Reclamation (Dept. of Interior)	Remaining federal lands	Military uses, wildlife habitat	23 (57)

Source: U.S. Department of Interior, U.S. Department of Agriculture, and U.S. Department of Defense

interspersed with open parkland. Regardless of the municipal land uses, city officials probably have a land use plan that includes zoning. However, land use plans seldom take into account all aspects of land as a resource both before and after development. The philosophy of most land use plans is that development is good because it increases the tax base, even though the revenue from these taxes is usually consumed providing services to the developed area.

Land use decisions are complex because they have multiple effects. If a tract of land is developed for housing, then roads, sewage lines, hospitals, and schools must be built nearby to accommodate the influx of people. Services are also required, such as new restaurants and shopping areas, which take up more land.

Ideally, public planning of land use should take into account all repercussions of the proposed land use, not just its immediate effects. It helps to begin with an inventory of the land, including its soil type, topography, types of organisms, endangered or threatened species, and historic or archaeological sites. By doing such an inventory, a public planning commission attempts to understand the value of the land as it currently exists, as well as its potential value after any proposed change.

In addition to providing people with open space for recreation and mental health, undeveloped land provides ecosystem services that must be recognized. These benefits should be compared with the possible economic benefits of development. In the long term, the best use of land may not be the use that provides immediate economic gain.

If the land will ultimately be developed, a well-designed development plan will be comprehensive. It will indicate which areas will remain open space, which will remain agricultural, and which will be zoned for high-, medium-, and low-density housing. (Chapter 9 contains additional discussion of land use patterns and zoning.)

REVIEW

1. What are ecosystem services?
2. What percentage of world land do urban areas occupy? How much is used for agriculture?

Wilderness, Parks, and Wildlife Refuges

LEARNING OBJECTIVES

- Describe the following federal lands and current issues of concern for each: wilderness, national parks, and national wildlife refuges.

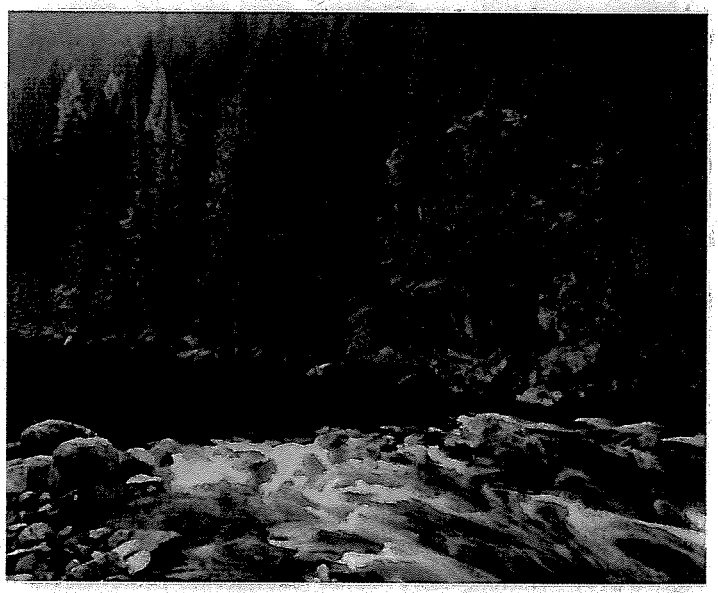
ness A protected f land in which no in development is permitted.

Wilderness encompasses regions where the land and its community of organisms are not greatly disturbed by human activities and where humans visit but do not permanently inhabit. The **Wilderness Act** of 1964 authorized the U.S. government to set aside federally owned land that retains its primeval character and lacks permanent improvements or human habitation as part of the **National Wilderness Preservation System**. These federal lands range in size from tiny islands to portions of national parks (42% of wilderness areas are in national parks), national forests (33% of wilderness areas), and national wildlife refuges (22% of wilderness areas). The Big Gum Swamp wilderness in Florida is only 5528 hectares (13,660 acres), whereas the Selway-Bitterroot Wilderness in Idaho is more than 530,000 hectares (1.3 million acres). Areas designated as wilderness are given the highest protection of any public lands (**Figure 17.3**). Wilderness areas are located within other types of federal lands, and the agencies that manage those lands also manage the wilderness areas. Thus, four government agencies—the NPS, USFS, FWS, and BLM—oversee the 758 wilderness areas that encompass 44.1 million hectares (109 million acres) of land.

Although mountains are the most common land safeguarded by this system, representative examples of other ecosystems have also been set aside, including tundra, desert, and wetlands. More than one-half of the lands in the National Wilderness Preservation System lie in Alaska, and western states contain much of the remaining lands. Because few sites untouched by humans exist in the eastern states, requirements were modified in 1975 so that the wilderness designation could be applied to certain federally owned lands where forests are recovering from logging.

Millions of people visit U.S. wilderness areas each year, and some areas are overwhelmed by this traffic: eroded trails, soil and water pollution, air pollution from cars, litter and trash, and human congestion predominate over quiet, unspoiled land. Government agencies now restrict the number of people allowed into each wilderness area at one time so that human use does not seriously affect the wilderness. Some of the most popular wilderness areas may require more intensive future management, such as building trails, outhouses, cabins, and campsites. These amenities are not encountered in true wilderness, posing a dilemma between wilderness preservation and human use and enjoyment of wild lands.

Limiting the number of human guests in a wilderness area does not control all factors that threaten wilderness. **Invasive species** that



Theodore Clutter / Science Source

Figure 17.3 The Selway-Bitterroot Wilderness area in Idaho.

become established in wilderness have the potential to upset the balance among native species. The white pine blister rust, a foreign fungus that kills white pine trees, has invaded the wilderness in the northern Rocky Mountains. Wilderness managers are concerned that declining white pine populations could harm the population of grizzly bears in the region. (Pine seeds are a major part of the grizzlies' diet.) The Wilderness Act specifies both the preservation of natural conditions and the avoidance of intentional ecological management. In this example, the only way to preserve as much as possible of the original wilderness may be to intentionally manipulate the white pine population by breeding and planting fungus-resistant trees.

Large tracts of wilderness, many in Alaska, have been added to the National Wilderness Preservation System since passage of the Wilderness Act in 1964. People who view wilderness as a nonrenewable resource support the designation of wilderness areas. Increasing the amount of federal land in the National Wilderness Preservation System is opposed by groups who operate businesses on public lands (such as timber, mining, ranching, and energy companies) and by their political representatives.

NATIONAL PARKS

In 1872 Congress established the world's first national park, Yellowstone National Park, in federal lands in the territories of Montana and Wyoming. The purpose of the park was to protect this land of great scenic beauty and biological diversity in an unimpaired condition for present and future generations. The **National Park System (NPS)** was originally composed of such large, scenic areas in the West as the Grand Canyon, Yosemite Valley, and Yellowstone (**Figure 17.4**). Today the National Park System has more cultural and historical sites—battlefields and historically important buildings and towns—than places of scenic wilderness. Additions to the NPS are made through acts of Congress, although the president has the authority to establish national monuments on federally owned lands.

Nancy Gift

Figure 17.4 Morning Glory Pool at Yellowstone. Boardwalks at Yellowstone protect hot springs from visitors, and protect visitors from hot springs. Yellowstone National Park has abundant geologic activity, in addition to its wolves and other wildlife.

The NPS was created in 1916 as a new federal bureau in the Department of the Interior and given the responsibility of administering the national parks and monuments. The NPS currently administers 397 sites, 59 of which are national parks. The total acreage administered by the NPS is 34.2 million hectares (84.4 million acres).

One of the primary roles of NPS is to teach people about the natural environment, management of natural resources, and history of a site by providing nature walks and guided tours of its parks. Exhibits along roads and trails, evening campfire programs, museum displays, and lectures are other educational tools. The popularity and success of U.S. national parks have led many other nations to follow the example of the United States in establishing national parks. Today, the UN Environment Programme identifies more than 3500 national parks, as defined by the International Union for the Conservation of Nation (IUCN), in nearly 100 countries. As in the United States, these parks usually have multiple roles, from providing biological habitat to facilitating human recreation.

Threats to U.S Parks All the problems plaguing urban areas are found in popular national parks during peak seasonal use, including crime; vandalism; litter; traffic jams; and pollution of the soil, water, and air. In addition, thousands of resource violations, from cutting live trees and collecting plants, minerals, and fossils to defacing historical structures with graffiti and setting fires, are investigated in national parks each year. Park managers have had to reduce visitor access to environmentally fragile park areas degraded from overuse.

Facilities at some of the largest, most popular parks, such as Yosemite, the Grand Canyon, and Yellowstone, were last upgraded some 30 years ago. Entrance fees account for about $132 million of the $2.2 billion a year the NPS spends. Although steps were taken to make parks more self-sufficient, they still depend on general tax revenues to pay for their operations.

Some national parks have imbalances in wildlife populations that involve declining populations of many species of mammals, including bears, white-tailed jackrabbits, and red foxes. Grizzly bears in national parks in the western United States are threatened. Grizzly bears require large areas of wilderness, and the human presence in national parks may adversely affect them. Many parks are too small to support grizzlies. Fortunately, so far grizzly bears have survived in sustainable numbers in Alaska and Canada.

Other mammal populations, notably elk, have proliferated. Elk in Yellowstone National Park's northern range increased from a population of 3100 in 1968 to a record high of 19,000 in 1994; populations have since dropped to roughly 4000 in 2012. Ecologists have documented that the elk reduce the abundance of native vegetation, such as willow and aspen, and seriously eroded stream banks. The reintroduction of wolves to Yellowstone, which began in 1995, is helping to reduce and redistribute the elk population (see the Chapter 5 introduction), and particularly keeping elk from overgrazing stream banks.

Pollution does not respect park boundaries, and parks are increasingly becoming *islands* of natural habitat surrounded by human development. Development on the borders of national parks limits the areas in which wild animals may range, forcing them into isolated populations. Ecologists have found that when

environmental stressors occur, several small "island" populations are more likely to become threatened than a single large population occupying a sizable range (see Chapter 16).

Natural Regulation A park management policy called **natural regulation** was introduced in Yellowstone National Park and many other U.S. national parks in 1968. Under natural regulation, the population of the elk herd in Yellowstone is allowed to fluctuate naturally because of varying weather conditions and predator populations such as grizzlies and wolves. Park managers do not try to maintain the herd at a consistent level by culling or artificially propagating elk. Because fires are an integral part of the Yellowstone ecosystem, wildfires in the park are not suppressed unless they threaten people or buildings. Park managers may intervene in other situations, such as to control invasive species or to restore native species (such as wolves).

natural regulation park management policy that involves ing nature take its most of the time, corrective actions rtaken as needed djust for changes used by pervasive human activities.

WILDLIFE REFUGES

The **National Wildlife Refuge System**, established in 1903 by President Theodore Roosevelt, is the most extensive network of lands and waters committed to wildlife habitat in the world. The National Wildlife Refuge System contains 560 refuges, with at least one in each of the 50 states, and encompasses 60.7 million hectares (150 million acres) of land. The various refuges represent all major ecosystems found in the United States, from tundra to temperate rain forest to desert, and are home to some of North America's most endangered species, such as the whooping crane. The mission of the National Wildlife Refuge System, which the FWS administers, is to preserve lands and waters for the conservation of fishes, wildlife, and plants of the United States. Wildlife-dependent activities, such as hunting, fishing, wildlife observation, photography, and environmental education, are permitted on parts of some wildlife refuges as long as they are compatible with scientific principles of fish and wildlife management.

REVIEW

1. What is the U.S. National Wilderness Preservation System? Which state has the most wilderness land?
2. What are some current concerns of the National Park System?
3. What is the purpose of the National Wildlife Refuge System?

Forests

LEARNING OBJECTIVES

- Define *sustainable forestry* and explain how monocultures are related to forestry.
- Describe national forests and current issues of concern.
- Define *deforestation*, including clear-cutting, and describe the main causes of tropical deforestation.
- Explain how conservation easements help private landowners protect forests from development.

Forests, important ecosystems that provide many goods and services to support human society, occupy about one-fourth of Earth's total land area. Timber harvested from forests is used for fuel, construction materials, and paper products. Forests supply nuts, mushrooms, fruits, and medicines and provide employment for millions of people worldwide. They also offer recreation and spiritual sustenance in an increasingly crowded world.

Forests provide a variety of beneficial ecosystem services. Forests influence local and regional climate conditions. If you walk into a forest on a hot summer day, you will notice that the air is cooler and moister than it is outside the forest. This is the result of a biological cooling process called *transpiration*, in which water from the soil is absorbed by roots, transported through plants, and then evaporated from their leaves and stems. Transpiration provides moisture for clouds, eventually resulting in precipitation (**Figure 17.5**). Thus, forests help maintain local and regional precipitation.

Forests play an essential role in regulating global biogeochemical cycles, such as those for carbon and nitrogen. Photosynthesis

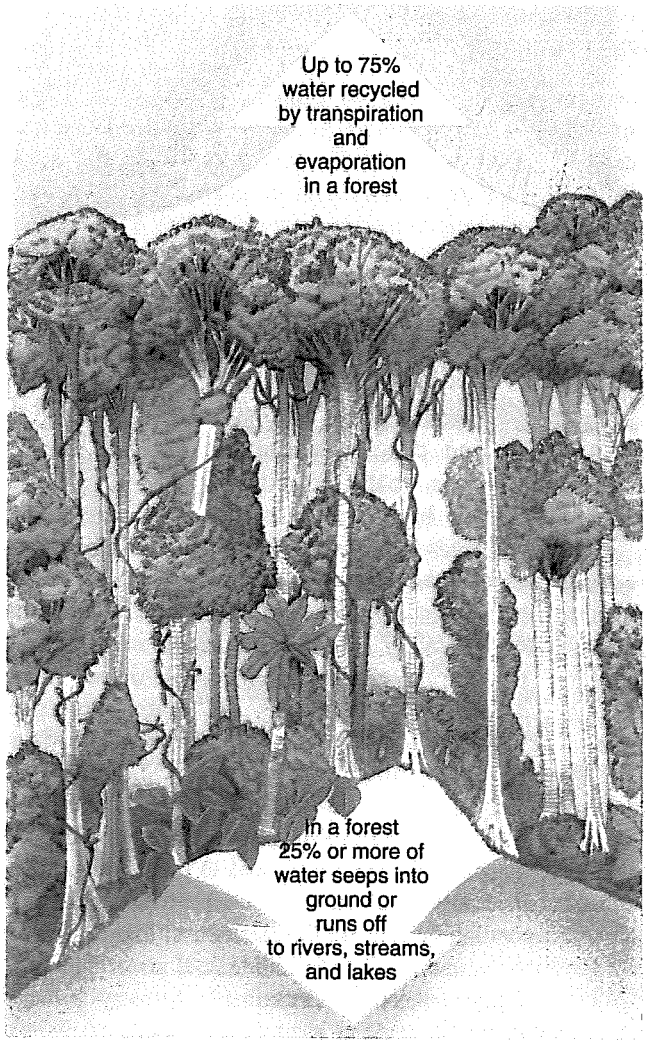


Figure 17.5 Role of forests in the hydrologic cycle. Forests return most (up to 75%) of the water that falls as precipitation to the atmosphere by transpiration. When an area is deforested, almost 100% of precipitation is lost as runoff.

by Earth's approximately 1 trillion canopy trees removes large quantities of heat-trapping carbon dioxide from the atmosphere and fixes it into carbon compounds. According to the Millennium Ecosystem Assessment, approximately as much carbon as is in the atmosphere is stored in trees. Forests thus act as carbon "sinks" that help mitigate global climate change. At the same time, oxygen, which almost all organisms require for cellular respiration, is released into the atmosphere.

Tree roots hold vast tracts of soil in place, reducing erosion and mudslides (the 2014 mudslide in Oso, Washington, mentioned in Chapter 14 was likely caused by deforestation). Forests protect watersheds because they pull deep water into upper soil layers; they absorb, hold, and slowly release water. This moderation of water flow provides a more regulated flow of water downstream, even during dry periods, and helps control floods and droughts. Forest soils remove impurities from water, improving its quality. In addition, forests provide a variety of essential habitats for many organisms, such as mammals, reptiles, amphibians, fishes, insects, lichens and fungi, mosses, ferns, conifers, and numerous kinds of flowering plants.

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Figure 17.6 Tree plantation. This intensively managed pine plantation is a monoculture, with trees of uniform size and age. Such plantations have little biodiversity and provide limited habitat, but they supplement the harvesting of trees in wild forests to provide the United States with the timber it requires. Photographed in Georgia.

FOREST MANAGEMENT

When forests are managed for timber production, their species composition and other characteristics are altered from their natural condition. Specific varieties of commercially important trees are planted, and those trees not as commercially desirable are thinned out or removed. *Traditional forest management* often results in low-diversity forests. In the southeastern United States, many tree plantations of young pine that are grown for timber and paper production are **monocultures** (**Figure 17.6**; see also Chapter 6). Tree plantations, however, have the potential to benefit remaining natural forests, provided that remaining forests are conserved and protected and that the plantations themselves do not replace natural forests.

monoculture Ecological simplification in which only one type of plant is cultivated over a large area.

sustainable forestry The use and management of forest ecosystems in a way that meets the needs of the current generation without compromising the ability of future generations to use the forests.

In recognition of the many ecosystem services performed by natural forests, many foresters now practice **sustainable forestry**, or **ecologically sustainable forest management**. Sustainable forestry maintains a mix of forest trees, by age and species, rather than a monoculture. This broader approach seeks to conserve forests for the long-term commercial harvest of timber and nontimber forest products. Sustainable forestry also attempts to sustain biological diversity by providing improved habitats for a variety of species, to prevent soil erosion and improve soil conditions, and to preserve watersheds that produce clean water. Effective sustainable forest management involves cooperation among environmentalists; loggers; farmers; indigenous people; and local, state, and federal governments.

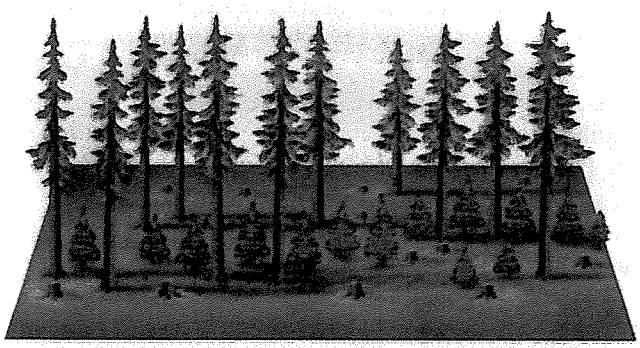
When logging adheres to sustainable forestry principles, unlogged areas are set aside as sanctuaries for organisms, along with **habitat corridors**—protected zones that connect isolated unlogged or undeveloped areas (see Figure 16.16). The purpose of habitat corridors is to provide escape routes should they be needed and to allow animals to migrate so that they can maintain healthy, diverse genetic populations.

The actual methods of ecologically sustainable forest management that distinguish it from traditional forest management are gradually being developed. These vary from one forest ecosystem to another, in response to different ecological, cultural, and economic conditions. In Mexico, many sustainable forestry projects involve communities that are economically dependent on forests. Because trees have such long life spans, scientists and forest managers of the future will judge the results of today's efforts.

Harvesting Trees According to the UN Food and Agriculture Organization (FAO), about 3.4 million cubic meters of wood (for fuelwood, timber, and other products) are harvested annually. The five countries with the greatest tree harvests are the United States, Canada, Russia, Brazil, and China; these countries currently produce more than half the world's timber. About 50% of harvested wood is burned directly as fuelwood or used to make charcoal. (Partially burning wood in a large kiln from which air is excluded converts the wood into charcoal.) Most fuelwood and charcoal are used in developing countries (discussed shortly). Highly developed countries consume more than three-fourths of the remaining 50% of harvested wood for paper and wood products.

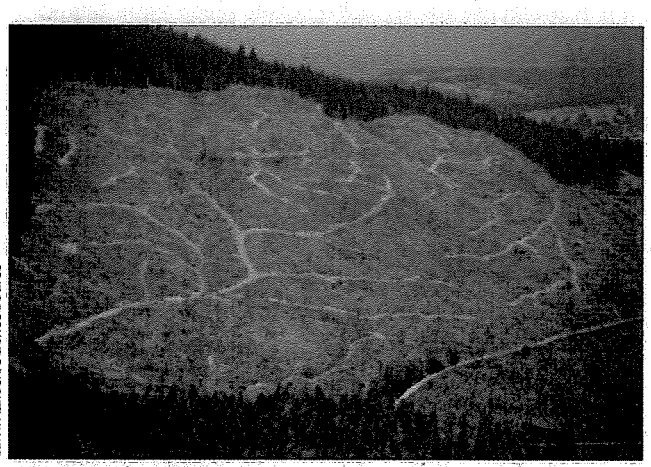
Loggers harvest trees in several ways—by selective cutting, shelterwood cutting, seed tree cutting, and clear-cutting (**Figure 17.7**). **Selective cutting**, in which mature trees are cut individually or in small clusters while the rest of the forest remains intact, allows the forest to regenerate naturally. The trees left by selective cutting produce seeds that germinate to fill the void.

(a) In selective cutting, the older, mature trees are selectively harvested from titme to time, and the forest regenerates itsels naturally.



(b) In shelterwood cutting, less desirable and dead trees are harvested. As younger trees mature, they produce seedlings, which continue to grow as the now-mature trees are harvested.

(c) Seed tree cutting nvolves the removal of all but a few trees, which are allowed to remain, providing seeds for natural regeneration.



Calvin Larsen/Science Source

(d) Aerial view of a large patch of clear-cut forest in Washington state. The lines are roads built to haul away the logs.

Figure 17.7 Harvesting trees.

Selective cutting has fewer negative effects on the forest environment than other methods of tree harvest, but it is not as profitable in the short term because timber removal from the forest requires greater amounts of labor.

The removal of all mature trees in an area over an extended period is **shelterwood cutting**. In the first year of harvest, undesirable tree species and dead or diseased trees are removed. The forest is then left alone for perhaps a decade, during which the remaining trees continue to grow and new seedlings become established. During the second harvest, many mature trees are removed, but some of the largest trees are left to shelter the young trees. The forest is then allowed to regenerate on its own for perhaps another decade. A third harvest removes the remaining mature trees, but by this time a healthy stand of younger trees is replacing the mature ones. Little soil erosion occurs with this method of tree removal, even though more trees are removed than in selective cutting.

cutting A logging ice in which all the in a stand of forest ut, leaving just the stumps.

In **seed tree cutting**, almost all trees are harvested from an area; a scattering of desirable trees is left behind to provide seeds for the regeneration of the forest. **Clear-cutting** is harvesting timber by removing all trees from an area. After the trees are removed by clear-cutting, the area is either allowed to reseed and regenerate itself naturally or is planted with one or more specific varieties of trees. Timber companies prefer clear-cutting because it is the most cost-effective way to harvest trees. Clear-cutting destroys biological habitats and increases soil erosion, particularly on sloping land. Sometimes the land is so degraded from clear-cutting that reforestation does not take place; whereas lower elevations are usually regenerated successfully, higher elevations are often difficult to regenerate.

DEFORESTATION

The most serious problem facing the world's forests is **deforestation**. According to *The Global Forest Resources 2010*, compiled by the FAO, forests shrank more than 13 million hectares (32 million acres) *annually* between 2000 and 2010. This amounts to a net 10-year loss equivalent to an area the size of Costa Rica. This estimate of forest loss does not take into account remaining forests that have been thinned or degraded by overharvesting, declining biological diversity, and reduced soil fertility.

deforestation The temporary or permanent clearance of large expanses of forest for agriculture or other uses.

Causes of deforestation include fires caused by drought, mining, land-clearing practices, expansion of agriculture, construction of roads in forests, tree harvests, and insects and diseases. When forests are converted to other land uses, they no longer make valuable contributions to the environment or to the people who depend on them. Forest destruction threatens people whose cultural and physical survival depends on the forests.

Deforestation results in decreased soil fertility through rapid leaching of the essential mineral nutrients found in most forest soils. Uncontrolled soil erosion, particularly on steep deforested slopes, affects the production of hydroelectric power as silt builds up behind dams. Increased sedimentation of waterways caused by soil erosion harms downstream fisheries. In drier areas, deforestation contributes to the formation of deserts (discussed shortly). When a forest is removed, the total amount of surface water that flows into rivers and streams actually increases, sometimes causing floods. Because the forest no longer regulates this water flow, the affected region experiences alternating periods of flood and drought.

Deforestation contributes to the extinction of many species. Many tropical species, in particular, have limited ranges within a forest, so they are especially vulnerable to habitat modification and destruction. Migratory species, including birds and butterflies, suffer from deforestation.

Deforestation contributes to regional climate changes. Trees release substantial amounts of moisture into the air; about 97% of the water that roots absorb from the soil is evaporated directly into the atmosphere. This moisture falls back to Earth in the hydrologic cycle (see Chapter 4). When a large portion of forest is removed, rainfall may decline and droughts may become more common in that region. Studies suggest that the local climate has become warmer and drier in parts of Brazil where huge tracts of the rain forest were burned. As the forest continues to shrink, it is possible that the changing regional climate will no longer be able to support the forest. Thus, large parts of what had once been tropical rain forest could become savanna.

Deforestation also contributes to an increase in global temperature, ocean acidification, and other global changes by releasing carbon originally stored in the trees into the atmosphere as carbon dioxide. Carbon dioxide enables the air to retain heat. The carbon in forests is released immediately if the trees are burned or more slowly when unburned parts decay. If trees are harvested and logs are removed, roughly one-half of the forest carbon remains as dead materials (branches, twigs, roots, and leaves) that decompose, releasing carbon dioxide. When an old-growth forest is harvested, researchers estimate that it takes about 200 years for the replacement forest to accumulate the amount of carbon that was stored in the original forest.

FOREST TRENDS IN THE UNITED STATES

In recent years, most temperate forests in the Rocky Mountains, Great Lakes region, and New England and other eastern states have been holding steady or even expanding. Expanding forests are the result of *secondary succession* on abandoned farms (see Chapter 5), commercial planting (tree plantations) on both private and public lands, and government protection. Although the returning forests generally do not have the biological diversity of original forests, many forest organisms have successfully become reestablished in regenerated forests.

More than half of U.S. forests are privately owned by individuals and corporations (**Figure 17.8**). Many private owners are under economic pressure, such as high property taxes, to subdivide the land and develop tracts of it for housing or shopping malls (see Meeting the Challenge: Preserving Forests in the Eastern States). Projected conversion of forests to agricultural, urban, and suburban lands over the next 40 years will probably have the greatest impact in the South, where more than 85% of forest is privately owned and logging is largely unregulated.

The **Forest Legacy Program** is a provision of the 1990 **Farm Bill** that helps private landowners protect environmentally important forestlands from development. Here's how the program, managed by the U.S. Department of Agriculture, works. A willing landowner sells some or all ownership rights, such as the right to develop the land, to the U.S. government, which then holds a **conservation easement**. The landowner usually continues to live and/or work on the property and can sell those rights not already sold to the government to other private individuals. All future property owners must honor the provisions of the conservation easement. In 2014, the Forest Legacy Program reported that it now protects more than 2.3 million acres of private forests threatened by development.

conservation easement A legal agreement that protect privately owned forest or other property from development for a spe fied number of years.

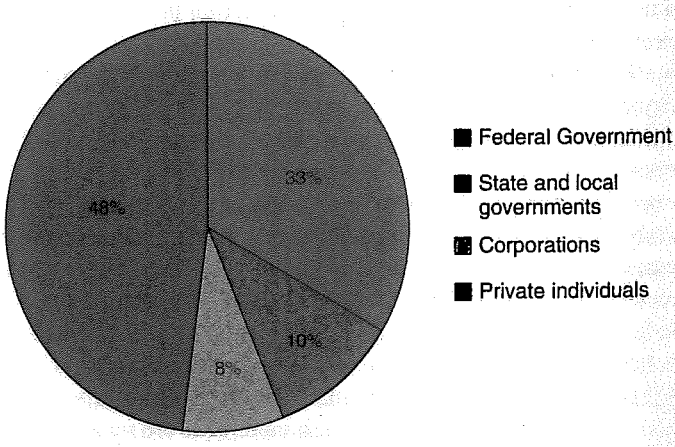


Figure 17.8 Forest ownership in the United States. Most forests (56%) are privately owned, either by individuals or corporations. (Data obtained from USDA/US Forest Service, 2006)

MEETING THE CHALLENGE

Preserving Forests in the Eastern States

Timber companies own most of the large tracts of privately owned forests in the eastern United States. Many of these temperate deciduous forests are becoming available for purchase because developers are willing to pay huge amounts of money for them. The timber companies find that selling the land is worth far more than they can earn from logging it. After purchasing the forest property, the developers cut down the trees and build residential communities, golf courses, and hunting clubs. Once development has occurred, there is no chance for the forest to ever regenerate.

Conservation organizations are buying some of these properties to preserve the forest. The mission of the Nature Conservancy, which was founded in 1951, is to "preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive." The Nature Conservancy has about 1 million members who contribute funds to purchase land and aquatic ecosystems. This organization typically collaborates with individual landowners, corporations (such as timber companies), state and federal governments, and indigenous people in a collaborative effort to preserve natural areas. Great Sand Dunes National Park, discussed in the chapter opener, was conserved in large part through the work of the Nature Conservancy.

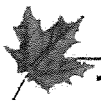
The Nature Conservancy and other conservation organizations have only enough money to purchase a small fraction (less than 2%) of the eastern forests that will probably be sold in the next few years. However, Nature Conservancy scientists prioritize their "wish list" to select the ecosystems that are most uncommon and that may provide habitat for endangered or threatened species. The lands encompassing those ecosystems are the ones that the Nature Conservancy works to obtain. Frequently, a deal is brokered with the timber companies so they can continue logging the ecologically valuable forests for five years or so. But at the end of the logging cycle, the land is allowed to undergo secondary succession and revert to forest. More important, the land is no longer available for economic development.

The **Nature Conservancy Appalachian Initiative** will protect a large portion of eastern forest that is considered one of the healthiest, most diverse temperate deciduous forests in the world. Saving landscape in the central Appalachians from mountaintop removal coal mining and from development not only preserves biological diversity in the forest but also protects water quality and aquatic organisms in the Chesapeake Bay and its tributaries. (The forest is part of the bay's watershed.) In addition, this initiative will provide safe drinking water for cities such as Baltimore, Harrisburg, Richmond, and Washington, D.C.

U.S. National Forests According to the USFS, the United States has 155 national forests encompassing 78 million hectares (193 million acres) of land, mostly in Alaska and western states. The USFS manages most national forests, with the remainder overseen by the BLM. National forests were established to provide U.S. citizens with the maximum benefits of natural resources such as fish, wildlife, and timber. Multiple uses include timber harvest; livestock forage; water resources and watershed protection; mining; hunting, fishing, and other forms of outdoor recreation; and habitat for fishes and wildlife. Recreation, which increased dramatically in national forests during the 1990s and early 2000s, ranges from camping at designated campsites to backpacking in the wilderness. Visitors swim, boat, picnic, and observe nature in national forests. With so many possible uses of national forests, conflicts inevitably arise, particularly between timber interests and those who wish to preserve the trees for other purposes.

Road building is a contentious issue in national forests, in part because the USFS builds taxpayer-funded roads that allow private logging companies access to the forest to remove timber. The money the USFS charges for timber concessions does not cover the cost for taxpayer-funded roads. Taxpayers also subsidize logging operations on lands the BLM manages. About 697,000 km (433,000 mi) of logging roads have been built throughout U.S. national forests. Road building in national forests is environmentally destructive if improper construction accelerates soil erosion and mudslides (particularly on steep terrain) and causes water pollution in streams. Biologists are concerned that so many roads fragment wildlife habitat and provide entries for disease organisms and invasive species.

Another issue in national forests is clear-cutting. We now examine the clear-cutting debate in the Tongass National Forest, which is located along Alaska's southeastern coast.

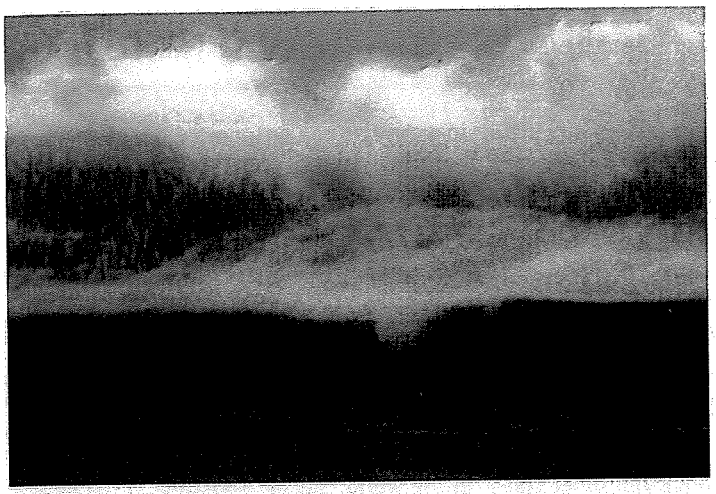


CASE IN POINT

TONGASS NATIONAL FOREST

Despite its northern location, the Tongass National Forest is one of the world's few temperate rain forests (**Figure 17.9**; also see Chapter 6 for a description of temperate rain forests). It is one of the wettest places in the United States. This moisture supports old-growth forest of giant Sitka spruce, yellow cedar, and western hemlock, some of which are 700 years old. Stream banks are lined with bent willows, ferns, mosses, and other vegetation. This forest, the largest in the National Forest System, provides habitat for a wealth of wildlife, such as grizzly bears and bald eagles.

About 70% of the old-growth forest in the Tongass has been logged. The Tongass is a prime logging area because a single large Sitka spruce may yield as much as 10,000 board feet of high-quality timber. The logging industry forms the basis of much of the local economy. Regeneration of mature forest after it was clear-cut



Richard Cummins/Getty Images

Figure 17.9 Tongass National Forest. This temperate rain forest is in southeastern Alaska along the Pacific Ocean.

is slow, on the order of several centuries. On Vancouver Island to the south of the Tongass, the trees in temperate rain forest that was clear-cut in 1911 have regrown to only 20% of their original size.

As in most national forests, it is expensive to log in the Tongass. To cover the high costs of operating, timber interests such as pulp mills rely on obtaining the timber from the federal government at below-market prices. This right was granted in 1954 by a contract that expired in the 1990s. In 1990, some members of Congress tried to pass the Tongass Timber Reform Act to force timber interests to pay market prices, but the legislation was bitterly opposed by other members of Congress. The compromise agreement, reached in 1997, provided timber to the mills at market prices. As a result of this legislation, clear-cut logging continued in the Tongass but at lower rates than in the past.

In 1999, the Tongass Land Management Plan of 1997 was modified after several dozen appeals were filed against it. The 1999 decision, called the *Modified 1997 Forest Plan*, protects an additional 100,000 acres of old-growth forest from logging. This brings the total protected area in the Tongass to 234,000 acres. (The total area of the Tongass National Forest is 17 million acres.) The modified plan increases timber harvest rotations from 100 years to 200 years in specially designated wildlife areas. This change reduces the impact of forest fragmentation and protects the Sitka black-tailed deer population, used for food by native tribes. The 1999 decision specifies that road density will be reduced to protect the habitat of wolves, bears, and other wildlife. It reduces the maximum quantity of timber harvested on a sustainable basis from 267 million board feet (the 1997 value) to 187 million board feet. This quantity is considered sufficient to meet the requirements of timber operators in the region.

The USFS officially adopted the controversial *Roadless Area Conservation Rule* in 2000, during the Clinton administration. A series of lawsuits challenging the rule ensued, initiated mainly by logging, mining, and gas and oil interests. In 2001, a U.S. district judge blocked the roadless rule, and plans proceeded to log several areas of Tongass National Forest that lack roads. In 2005, the George W. Bush administration issued new rules making it easier to build roads in pristine parts of national forests for logging, mining, and other development; these rules put the decision to log in the hands of individual states.

In 2008, a new amendment to the Forest Plan for the Tongass Forest was implemented. Data were collected for five years, and as of 2013, public input regarding the next five-year plan was being gathered. Whether Tongass Forest will be increasingly logged or conserved depends on the input and influence of various interest groups. ■

TRENDS IN TROPICAL FORESTS

There are two main types of tropical forests: tropical rain forests and tropical dry forests. In places where the climate is warm and moist throughout the year—with about 200 or more cm (at least 79 in.) of precipitation annually—**tropical rain forests** prevail. Tropical rain forests are found in Central and South America, Africa, and Southeast Asia, but almost half of them are in just three countries: Brazil, the Democratic Republic of the Congo, and Indonesia (**Figure 17.10**).

In tropical areas where annual precipitation is less than in tropical rain forests but still enough to support trees, including regions subjected to a wet season and a prolonged dry season, **tropical dry forests** occur. During the dry season, tropical trees shed their leaves and remain dormant, much as temperate trees do during the winter. India, Kenya, Zimbabwe, Egypt, and Brazil are examples of countries that have tropical dry forests.

Most of the remaining undisturbed tropical forests, which lie in the Amazon and Congo River basins of South America and Africa, are being cleared and burned at a rate unprecedented in human history. Tropical forests are also being destroyed at an extremely rapid rate in southern Asia, Indonesia, Central America, and the Philippines.

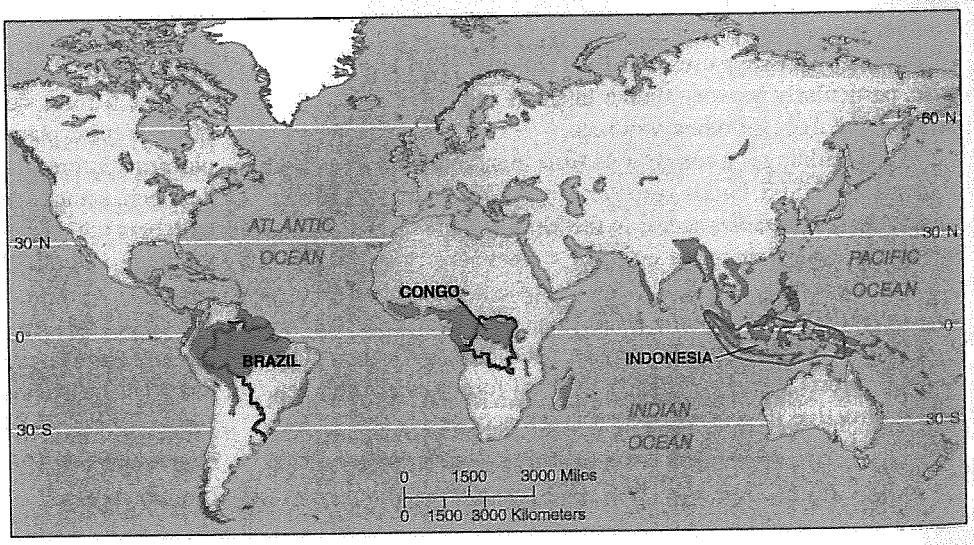
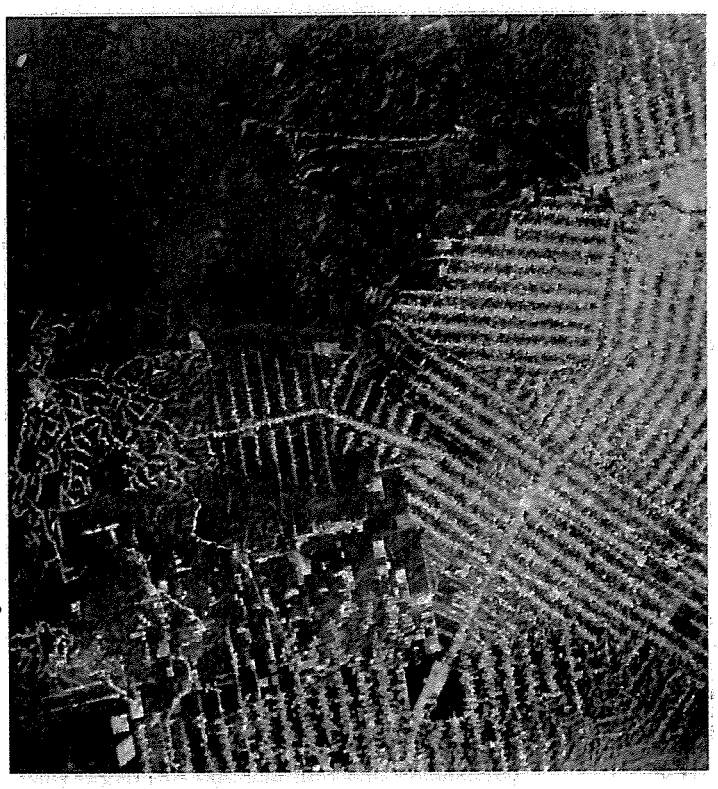


Figure 17.10 Distribution of tropical rain forests. Rain forests (green areas) are located in Central and South America, Africa, and Southeast Asia. Many of the remaining tropical rain forests are highly fragmented.

ENVIRONEWS

Shopping in the Rain Forest

The mostly contiguous Brazilian Amazon rain forest is interrupted by five Amazonian cities (Belém, Manaus, Porto Velho, Macapa, and Rio Branco) whose populations exceed 300,000 people. These city dwellers clamor for the amenities associated with economic development, and the arrival of shopping malls has answered their needs. Like malls in other parts of the world, Amazonian malls have modern architecture, air conditioning, and a variety of local and international stores in which to spend money for consumer goods. So far, the malls have been built on land that was deforested decades ago and so are not contributing to deforestation. However, an ever-expanding network of roads connects the malls to smaller cities and towns throughout the Amazon region, and these roads do accelerate the pace of deforestation. Most environmentalists recognize that shopping malls are part of a global economic trend. Instead of opposing urban shopping malls, many environmentalists are focusing on ways to bring sustainable development to the rural people living in the rain forest.



National Remote Sensing Centre Ltd/Science Source

Figure 17.11 Satellite photograph of human settlements along a portion of road in Brazil's tropical rain forest. Numerous smaller roads extend perpendicularly from the main roads. As the farmers settle along the roads, they clear out more forest (dark green) for their croplands and pastures (tans and pinks). How does road building and its accompanying deforestation contribute to climate change?

Why Are Tropical Rain Forests Disappearing? Several studies show a strong correlation between population growth and deforestation. More people need more food, so the forests are cleared for agricultural expansion. Tropical deforestation is a problem that cannot be attributed simply to population pressures, however. The main causes of deforestation vary from place to place, and a variety of economic, social, and government factors interact to cause deforestation (**Figure 17.11**).

Keeping in mind that tropical deforestation is complex, three agents—subsistence agriculture, commercial logging, and cattle ranching—are considered the most immediate causes of deforestation. Other reasons for the destruction of tropical rain forests include mining and dam construction for hydroelectric power, which inundates large areas of forest.

Subsistence Agriculture. **Subsistence agriculture**, in which a family produces just enough food to feed itself, accounts for more than half of tropical deforestation. In many developing countries where tropical rain forests occur, the majority of people do not own the land they live and work on. In Brazil, 5% of the farmers own 70% of the land. Most subsistence farmers have no place to go except into the forest, which they clear to grow food.

Subsistence farmers often follow loggers' access roads until they find a suitable spot. They first cut down the trees and allow them to dry, then they burn the area and plant crops immediately after burning; this is known as **slash-and-burn agriculture** (discussed further in Chapter 18). The yield from the first crop is often quite high because the nutrients that were in the burned trees are now available in the soil. However, soil productivity declines at a rapid rate, and subsequent crops are poor. In a short time, the people farming the land must move to a new part of the forest and repeat the process. Cattle ranchers often claim the abandoned land for grazing because land not rich enough to support crops can still support livestock.

Slash-and-burn agriculture done on a small scale, with plenty of forest to shift around in so that periods of 20 to 100 years occur between cycles, may be sustainable. The forest regrows rapidly after a few years of farming. But when human population density is high, the land is not allowed to lie uncultivated long enough to recover. Globally, at least 200 million subsistence farmers obtain a living from slash-and-burn agriculture, and the number is growing. Moreover, only half as much forest is available today as was available 50 years ago.

Commercial Logging. Vast tracts of tropical rain forests, particularly in Southeast Asia, are harvested for export abroad. Most tropical countries allow commercial logging to proceed at a much faster rate than is sustainable. Unmanaged tropical deforestation, rather than contributing to economic development, depletes a valuable natural resource faster than it can regenerate for sustainable use.

Cattle Ranching and Agriculture for Export. Some tropical deforestation is carried out to provide open rangeland for cattle (**Figure 17.12**). Cattle ranching, which employs relatively few local people (ranching does not require much labor), is particularly important in Latin America. Some of the beef raised on these ranches, often owned by foreign companies, is exported to highly developed countries, although much is consumed locally. After the forests are cleared, cattle graze on the land for perhaps 20 years, after which time the soil fertility is depleted. When this occurs, shrubby plants, known as **scrub savanna**, may take over the range.

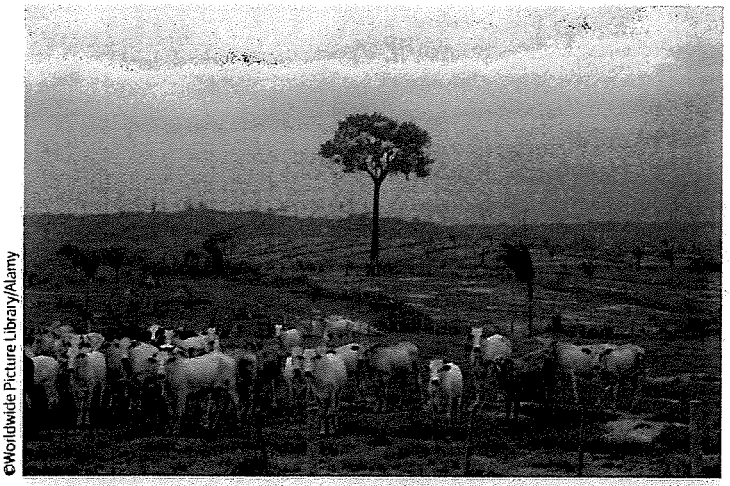


Figure 17.12 Deforestation in Brazil. This pasture was a rain forest cleared to graze cattle. One rainforest tree was left in the field—a Brazil nut tree.

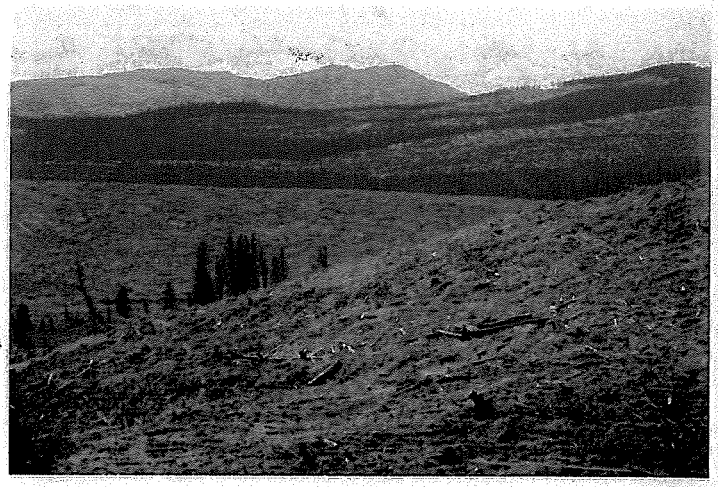


Figure 17.13 Logging in Canada's boreal forest. About 80% of Canada's forest products are exported to the United States. Photographed in Alberta, Canada.

A considerable portion of forestland is cleared for plantation-style agriculture, which produces export crops such as citrus fruits, palm fruit (for margarine), bananas, and soybeans (see Figure 16.9).

Why Are Tropical Dry Forests Disappearing? Tropical dry forests are being destroyed at a rapid rate, primarily for fuelwood. About half of the wood consumed worldwide is used as heating and cooking fuel by much of the developing world. The unsustainable use of wood has led to a fuelwood crisis in many developing countries. The 2 billion or so people that the FAO says cannot get enough fuelwood to meet basic needs, such as boiling water and cooking, are at risk of waterborne infectious diseases (see Table 21.1 for a list of some human diseases transmitted by polluted water). Often the wood cut for fuel is converted to charcoal, which is then used to power steel, brick, and cement factories. Charcoal production is extremely wasteful: 4.0 metric tons (4.5 tons) of wood produce enough charcoal to fuel an average-sized iron smelter for only six minutes.

BOREAL FORESTS AND DEFORESTATION

Although tropical forests have been depleted extensively, they are not the only forests at risk. Extensive logging of certain boreal forests began in the late 1980s and early 1990s and continues today. Boreal forests occur in Alaska, Canada, Scandinavia, and northern Russia. Coniferous evergreen trees such as spruce, fir, cedar, and hemlock dominate these northern forests. Boreal forests comprise the world's largest biome, covering about 11% of Earth's land area.

Boreal forests, harvested primarily by clear-cut logging, are currently the primary source of the world's industrial wood and wood fiber. The annual loss of boreal forests is estimated to encompass an area twice as large as the Amazonian rain forests of Brazil.

Canada is the world's biggest timber exporter (**Figure 17.13**). About 1 million hectares (2.5 million acres) of Canadian forests are logged annually, and most of Canada's forests are under logging tenures. (*Tenures* are agreements between provinces and companies that give companies the right to cut timber.) Based on harvest quotas, logging in Canada was widely considered unsustainable until recently. In 2010, logging companies and environmental groups brokered an agreement in which logging was suspended in more than 300,000 km² (about 116,000 mi²) of boreal forest, an area the size of Great Britain. An additional 385,000 km² (about 149,000 mi²) were designated for restricted logging using sustainable guidelines.

Extensive tracts of Siberian forests in Russia are also harvested, although exact estimates are unavailable. Alaska's boreal forests are at risk because the U.S. government may increase logging on public lands (recall the earlier discussion of logging in Alaska's temperate rain forest).

REVIEW

1. What is sustainable forestry?
2. Why is the fact that U.S. national forests were created for multiple uses often a contentious issue?
3. What is deforestation?
4. How do conservation easements protect forests from development?

Rangelands and Agricultural Lands

LEARNING OBJECTIVES

- Describe public rangelands and current issues of concern.
- Define *desertification* and explain its relationship to overgrazing.
- Discuss trends in U.S. agricultural land, such as encroachment of suburban sprawl.

Rangelands are grasslands, in both temperate and tropical climates, that serve as important areas of food production for humans by providing fodder for livestock such as cattle, sheep, and goats (**Figure 17.14**). Rangelands may be mined for minerals and

rangeland Land that is not intensively managed and is used for grazing livestock.

Nancy Gift

Figure 17.14 Rangeland. When the carrying capacity of rangeland is not exceeded, it is a renewable resource, useful both for ranchers and wildlife, like this pronghorn antelope. Photographed in Wyoming.

energy resources, used for recreation, and preserved for biological habitat and for soil and water resources. The predominant vegetation of rangelands includes grasses, forbs (small herbaceous plants other than grasses), and shrubs. Rangelands differ from pastures in that pasture plants have been cultivated specifically for grazing by livestock, whereas rangeland plant communities are native, not cultivated, and are naturally suitable for grazing animals.

RANGELAND DEGRADATION AND DESERTIFICATION

Grasses, the predominant vegetation of rangelands, have a *fibrous root system*, in which many roots form a diffuse network in the soil to anchor the plant. Plants with fibrous roots hold the soil in place quite well, thereby reducing soil erosion. Grazing animals eat the leafy shoots of the grass, and the fibrous roots continue to develop, allowing the plants to recover and regrow to their original size.

Carefully managed grazing is beneficial for grasslands. Because the vegetation is adapted to grazing, the removal of mature vegetation by grazing animals stimulates rapid regrowth. At the same time, the hooves of grazing animals moving in groups disturb the soil surface enough to allow rainfall to more effectively reach the root systems of grazing plants and the seeds of new plants. Several studies around the world have reported that moderate levels of grazing encourage greater plant diversity. Rangeland health can be maintained by management of the movement and number of grazing animals.

When the **carrying capacity** (see Chapter 5) of a rangeland is exceeded and recovery times are not sufficient for healthy regrowth after grazing, grasses and other plants are said to be **overgrazed**. When plants die, the exposed soil is susceptible to erosion. Sometimes other plants that can tolerate the depleted soil invade an overgrazed area. In parts of the Texas Hill Country that were overgrazed, junipers (which are not good forage food) replaced the lush grasses. Unpalatable or poisonous plants can successfully invade overgrazed pasture, because these plants remain uneaten by foraging animals.

ergrazing Destruction of vegetation caused by so many animals grazing too close to he soil or repeatedly ng the plants before plete root and shoot regrowth.

Most of the world's rangelands lie in semiarid areas that have natural extended droughts. During dry periods, the carrying capacity of the rangeland is considerably lower because the lack of precipitation reduces plant productivity. Native grasses in these drylands can survive a severe drought: The aerial portion of the plant dies back, but the extensive root system remains alive and holds the soil in place. When the rains return, the roots help support new shoot growth.

When extended drought results in a need for longer recovery times or smaller numbers of grazers, once-fertile rangeland can convert to desert if stocking patterns are not changed. The reduced grass cover caused by overgrazing allows winds to erode the soil, reducing organic matter and soil seedbanks needed for ecosystem recovery. Even when the rains return, **land degradation** is so extensive that the rangeland may not recover. Water erosion removes the little bit of remaining topsoil, and the sand left behind forms dunes. This progressive degradation, which induces unproductive desertlike conditions on formerly productive rangeland (or tropical dry forest), is called **desertification**. It reduces the agricultural productivity of economically valuable land, forces many organisms out, and threatens endangered species.

land degradation The natural or human-induced process that decreases the future ability of the land to support crops or livestock.

desertification Degradation of once-fertile rangeland, agricultural land, or tropical dry forest into nonproductive desert.

Worldwide, desertification seems to be on the increase. Each year since the mid-1990s, the United Nations estimates that 3560 km^2 (1374 mi^2) of land—an area about the size of Rhode Island—has turned into desert. However, many people are working to reverse this trend. The Green Belt Movement, founded by Wangari Maathai of Kenya, helps people to plant and nurture trees in areas at risk of desertification. The Chipko Movement in India, like the Green Belt Movement, particularly encouraged and empowered women to help prevent deforestation.

We do not know the extent to which desertification results from natural fluctuations in climate versus population pressures and human activities. Currently, many ecologists who study desertification do not think human activities are the main cause of desert encroachment. For example, several years of satellite data support the hypothesis that natural climate variation is the primary factor responsible for the shifting boundary between the southern edge of the Sahara Desert and the African Sahel. Ecologists acknowledge that human activities and overpopulation contribute to degradation in the Sahel but say that fluctuations in climate are causing the desert to advance southward into the Sahel (during drier years) and then retreat (during wetter years). Of course, climate change is also a likely factor, and in this way, desertification of rangelands relates directly to deforestation, since deforestation contributes to climate change.

About 30% of the total human population lives in the Sahel or other rangelands that border deserts. One of the consequences of desertification is a decline in agricultural productivity, and studies have shown that when an area cannot feed its people, they emigrate. For example, more Senegalese live in certain regions of France than in their native villages in Africa. On the other hand, forcing nomadic peoples, such as the Tuareg of the Sahara, to adopt more settled lifestyles may exacerbate desertification by forcing them to reintroduce animals back to a grazed area before

plants are again suitable for grazing. According to the UN Environment Programme, about 135 million people worldwide are in danger of displacement as a result of desertification. The World Bank, which estimates that desertification costs $42.3 billion per year in economic losses, is beginning to emphasize programs with sustainable agricultural systems for dryland areas.

RANGELAND TRENDS IN THE UNITED STATES

Rangelands make up approximately 30% of the total land area in the United States and occur mostly in the western states. Of this, approximately two-thirds is privately owned. Much of the private rangeland is under increasing pressure from developers, who want to subdivide the land into lots for houses and condominiums. To preserve the open land, conservation groups often pay ranchers for conservation easements that prevent future owners from developing the land. An estimated 400,000 hectares (1 million acres) of private rangeland are now protected by conservation easements.

Excluding Alaska, there are at least 89 million hectares (220 million acres) of public rangelands. The BLM, guided by the **Taylor Grazing Act** of 1934, the **Federal Land Policy and Management Act** of 1976, and the **Public Rangelands Improvement Act** of 1978, manages most of the approximately 69 million hectares (170 million acres) of public rangelands. The USFS manages an additional 20 million hectares (50 million acres).

Overall, the condition of public rangelands in the United States has slowly improved since the low point of the Dust Bowl in the 1930s (see Chapter 14). Much of this improvement is attributed to fewer livestock being permitted to graze the rangelands after passage of the Taylor Grazing Act in 1934. Better livestock management practices, such as controlling the distribution of animals on the range through fencing or herding, as well as scientific monitoring, have contributed to rangeland recovery. But restoration is slow and costly, and more is needed. Rangeland management includes seeding in places where plant cover is sparse or absent, conducting controlled burns to suppress shrubby plants, constructing fences to allow rotational grazing, controlling invasive weeds, and protecting habitats of endangered species. Most livestock operators today use public rangelands in a way that results in their overall improvement.

Grazing Fees on Public Rangelands The federal government distributes permits to private livestock operators that allow them to use public rangelands for grazing in exchange for a fee. (In 2012 the monthly grazing fee was $1.35 per animal on lands managed by the BLM and USFS. The comparable monthly cost on private land is around $15.) The permits are held for many years and are not open to free-market bidding by the general public—that is, only ranchers who live in the local area are allowed to obtain grazing permits.

Some environmental groups are concerned about the ecological damage caused by overgrazing of public rangelands and want to reduce the number of livestock animals allowed to graze. They want public rangelands managed for other uses, such as biological habitat, recreation, and scenic value, rather than exclusively for livestock grazing. To accomplish this goal, they would like to purchase grazing permits and then set aside the land. At the very least, some groups, like the Center for Biological Diversity, would like to see grazing fees increased to a level closer to the open market rate.

Some economists have joined environmentalists in criticizing the management of federal rangelands. According to policy analysts at Taxpayers for Common Sense, in 2010 taxpayers contributed at least $115 million more than the grazing fees collected on public rangelands. This money is used to manage and maintain the rangelands, including installing water tanks and fences, and to fix the damage from overgrazing. Taxpayers for Common Sense and other free-market groups want grazing fees to cover all costs of maintaining herds on publicly owned rangelands.

AGRICULTURAL LANDS

The United States has more than 120 million hectares (300 million acres) of **prime farmland**, land that has the soil type, growing conditions, and available water to produce food, forage, fiber, and oilseed crops. Certain areas of the country have large amounts of prime farmland. For example, 90% of the *Corn Belt*, a corn-growing region in the Midwest encompassing parts of six states, is considered prime farmland. Not all prime farmland is used to grow crops; approximately one-third contains roads, pastures, rangelands, forests, feedlots, and farm buildings.

Traditionally, farming was a family business. However, larger agribusiness conglomerates that operate less labor intensively are replacing the family farm. As of 2010, there were 2.2 million farms in the United States, as compared to 6.4 million in 1920. In the same period, the average farm size increased from 60 hectares (148 acres) to 169 hectares (418 acres).

Much of prime U.S. agricultural land is falling victim to urbanization and suburban sprawl by being converted into parking lots, housing developments, and shopping malls—the same kinds of development threatening private rangelands. Both natural ecosystems and agricultural lands adjacent to urban areas are being developed (**Figure 17.15**). In certain areas of the United States, loss of rural land is a significant problem. According to the American Farmland Trust, the top five U.S. farm areas threatened

AP Photo/York Daily Record, Bil Bowden

Figure 17.15 Suburban spread onto agricultural land. Homes and businesses occupy land that was once cornfields in York County, Pennsylvania.

by population growth and urban/suburban spread are California's Central Valley, south Florida, California's coastal region, the Mid-Atlantic Chesapeake region (Maryland to New Jersey), and the North Carolina Piedmont. More than 160,000 hectares (400,000 acres) of prime U.S. farmland are lost each year.

The 1996 Farm Bill included funding for the establishment of a national *Farmland Protection Program.* (Many states and local jurisdictions also have farmland protection programs.) This voluntary program helps farmers keep their land in agriculture. The farmers sell conservation easements that prevent them or future landowners from converting their land to nonagricultural uses. Such easements can protect farmland in areas where local zoning laws might prioritize development over agricultural uses. The conservation easements are in effect from a minimum of 30 years to forever. As with other conservation easements, the farmers retain full rights to use their property—in this case, for agricultural purposes. Funding of the Farmland Protection Program is subject to annual appropriations from Congress.

REVIEW

1. How do rangelands differ from pasture? What is the carrying capacity of a rangeland?
2. How is desertification related to rangeland management?
3. What human activity is threatening many acres of prime farmland?

Wetlands and Coastal Areas

LEARNING OBJECTIVE

- Describe current threats to freshwater and coastal wetlands.

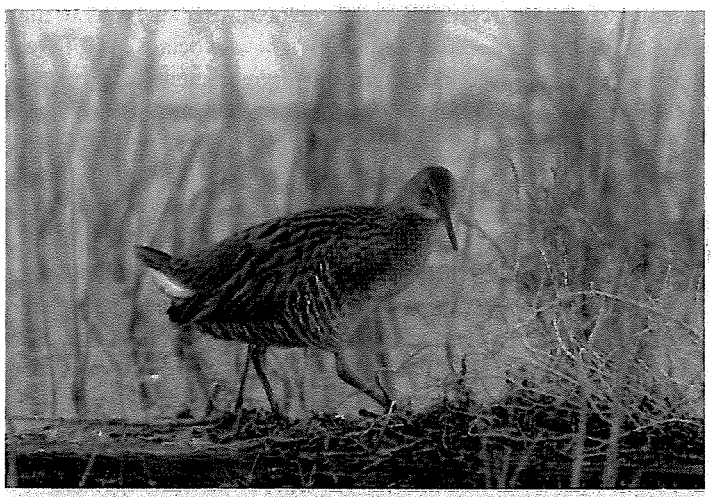
lands Lands that isually covered by allow water for at irt of the year and ave characteristic nd water-tolerant vegetation.

Wetlands are lands transitional between aquatic and terrestrial ecosystems (see Figure 6.16). People used to think the only benefit of wetlands was to provide habitat for migratory waterfowl and other wildlife. In recent years, the many ecosystem services that wetlands perform have been recognized, and estimates of their economic value have increased accordingly. Wetlands recharge groundwater and reduce damage from flooding because they hold excess water when rivers flood their banks. Wetlands improve water quality by trapping and holding nitrates and phosphates from fertilizers, and they help cleanse water that contains sewage, pesticides, and other pollutants. Wetlands provide habitat for many species listed as endangered or threatened; these include up to half of all fish species, one-third of all bird species, and one-sixth of all mammal species listed on the U.S. endangered or threatened species lists. Freshwater wetlands produce many commercially important products, including wild rice, blackberries, cranberries, blueberries, and peat moss. They are sites for fishing, hunting, boating, bird watching, photography, and nature study.

Many human activities threaten wetlands, including drainage for agriculture or mosquito control and dredging for navigation. Other threats include channelization and construction of dams, dikes, or seawalls for flood control; filling in for solid waste disposal, road building, and residential and industrial development; conversion for aquaculture (fish farming); mining for gravel, phosphate, and fossil fuels; and logging. In the United States, wetlands have been shrinking an estimated 24,300 hectares (60,000 acres) per year since 1985. This represents a slower rate of loss than in previous years. In the contiguous 48 states, more than half of the more than 89.4 million hectares (221 million acres) of wetlands that originally existed during colonial times are gone. Most of the loss since the 1950s has been caused by farmers converting wetlands to cropland. The greatest percentage declines in wetlands have occurred in the agricultural states of Ohio, Indiana, Iowa, and California. The greatest total acreage declines in wetlands have occurred in Florida, Louisiana, and Texas.

The loss of wetlands is legislatively controlled by a section of the 1972 **Clean Water Act**. This legislation, up for renewal since 1997, does a reasonably good job of protecting coastal wetlands but a poor job of protecting inland wetlands—and most wetlands occur inland. The **Emergency Wetlands Resources Act** of 1986 authorized the FWS to inventory and map U.S. wetlands. These maps have many uses, such as planning protection for drinking-water supplies, siting development projects, and making recovery plans for endangered species.

Since 1989, the United States has attempted to prevent any new net loss of wetlands by conserving existing wetlands and restoring some that were lost. Development of wetlands is allowed only if a corresponding amount of previously converted wetlands is restored. However, not all wetland restorations are successful, and there is no routine tracking of compliance. For example, the Sweetwater Marsh was constructed along San Diego Bay in 1984 by the California Department of Transportation, which was legally required to do so when it destroyed a similar marsh during road construction. One of the main purposes of the reconstructed marsh was to provide habitat for the light-footed clapper rail, an endangered species (**Figure 17.16**). The clapper rail never became established in the reconstructed marsh. Ecologists determined that the marsh grass in Sweetwater Marsh was too short for the bird to use for nesting. That species of marsh grass grows significantly taller in natural marshes, where the sediments retain enough nitrogen



Richard R. Hansen/Science Source

Figure 17.16 Light-footed clapper rail. This endangered species is found in certain California salt and brackish marshes.

to fertilize it. The reconstructed marsh's sediments, which were dredged from San Diego Bay's shipping channel and obtained from an old urban dump, are too sandy to retain nitrogen.

Thus, the policy of preventing wetlands loss is only partially successful, and wetlands loss continues, though at a slower rate. Two factors complicate the wetlands policy: (1) confusion and dissent about the definition of wetlands, which was not spelled out in the original Clean Water Act, and (2) the question of who owns wetlands. In 1989, a team of government scientists developed a comprehensive, scientifically correct definition of wetlands. (The definition is technical and beyond the scope of this text.) It provoked an outcry from farmers and real estate developers, who perceived it as an economic threat to their property values. Largely in response to their criticisms, politicians attempted to narrow the definition of wetlands several times during the 1990s, removing marginal wetlands that were not as wet as swamps or marshes. This narrower definition ignored decades of wetlands research and excluded about one-half of existing U.S. wetlands from protection.

In 1992, Congress asked the National Research Council to help settle the issue because it had become so controversial. The council published its wetlands study in 1995, urging Congress to put the wetlands debate back on a more scientific footing. The council recommended that because shallow wetlands and intermittent wetlands perform the same ecosystem services as swamps and marshes, they should be regulated by the same principles. The council study generated an even greater debate in Congress, illustrating that more complete scientific information does not necessarily solve problems when stakes are high and values diverge. During the late 1990s and early 2000s, a series of federal court cases involving wetland protection resulted in conflicting decisions. To further complicate the matter, in 2006 the Supreme Court asked the U.S. Army Corp of Engineers to determine which wetlands deserve federal protection under the Clean Water Act. In 2014, the EPA ruled that upstream waters must be protected to support wetland health.

The federal government owns less than 25% of wetlands in the lower 48 states; the remaining 75% is privately owned. This means that private citizens control whether wetlands are protected and preserved or developed and destroyed. Because of the traditional rights of private land ownership in the United States, landowners resent the federal government's telling them what they may or may not do with their properties. Property-rights advocates in Congress side with landowners in thinking the government has overprotected wetlands, though many of these property rights advocates have economic ties to development and mining groups.

Congress authorized the establishment of the *Wetlands Reserve Program* (WRP) under the **Food Security Act** of 1985 and its amendments. The WRP is a voluntary program that seeks to restore and protect privately owned freshwater wetlands that were previously drained, such as those drained for conversion to cropland. Participants are offered financial incentives to restore the wetlands, and they can establish conservation easements to protect them. If a property owner establishes a permanent easement, the WRP pays all restoration costs and an amount equal to the agricultural value of the land. As with other conservation easements, the landowner continues to control access to the land. The Natural Resources Conservation Service administers the WRP, which is funded annually by Congress and is subject to budget cuts.

Buildings within flood zones are subject to higher flood insurance rates. Development and behavior of private landowners may therefore be influenced through flood zone maps, which were redrawn by the *Federal Emergency Management Agency* (FEMA) in 2013. Development may be hindered in flood zone areas, which may help protect many wetlands, both inland and in coastal areas.

COASTLINES

Coastal wetlands, also called saltwater wetlands, provide food and protective habitats for many aquatic animals. They could be considered the ocean's nurseries because so many marine fishes and shellfish spend the first parts of their lives there. In addition to being highly productive, coastal wetlands protect coastlines from erosion, enhance water quality, and reduce damage from hurricanes and other natural events. Intact coastal wetlands act as buffer zones that moderate the effects of tides and storms. Sandy beaches along intact coastal wetlands are alternately washed away and replenished by wave action.

Historically, tidal marshes and other coastal wetlands were regarded primarily as mosquito breeding grounds. Coastal wetlands throughout the world have been drained, filled in, or dredged out to turn them into "productive" endeavors such as industrial parks, housing developments, and marinas. Agriculture contributes to the demise of coastal wetlands, which are drained for their rich soil. Other human endeavors that cause the destruction of coastal wetlands include timber harvesting and fish farming (see Figure 18.19). In the United States, people have belatedly recognized the importance of coastal wetlands in protecting against shoreline erosion, and Congress has passed some legislation to slow their destruction. Many people became more willing to protect coastal wetlands from development (or redevelopment) following Hurricane Sandy in 2012, which devastated many densely populated areas of the eastern United States.

Seawalls and Sand Dunes During the past century, shoreline erosion has increased along many coastlines. Many property owners protect their shoreline by adding retaining walls or rebuilding sand dunes. When seawalls are built parallel to the beach, however, the beach rapidly erodes away, including beach on properties adjacent to the wall. Most legislation protects beaches at the shoreline from seawalls by *rolling easements*, which prioritize public access to the shore over property owners' rights to build walls. Few laws protect shoreline along bays and sounds, and walls are rapidly replacing these tidal shorelines in many areas of the United States. However, sand dunes also show great potential for decreasing coastal flooding (**Figure 17.17**); the force of tides and waves can be absorbed by sand, thereby decreasing the impact inland. Because sea levels have begun to rise due to global climate change and are expected to rise even more rapidly as the 21st century progresses, protection and construction of sand dunes can have an important role in protecting coastal areas.

Coastal Demographics Many coastal areas are overdeveloped, highly polluted, and overfished. Although more than 50 countries have coastal management strategies, their focus is narrow and usually deals only with the economic development of a thin strip of land that directly borders the ocean. Coastal management

Figure 17.17 Storm damage on a coastal dune. This boardwalk, on a beach on the Atlantic Coast of France, demonstrates the force of a coastal storm. Without sand dunes, the force of storms is directed inland, often in developed areas.

plans generally do not integrate the management of both land and offshore waters, nor do they take into account the main reason for coastal degradation—human numbers. Perhaps 3.8 billion people—more than half of the world's population—live within 150 km (93 mi) of a coastline. Demographers project that three-fourths of all humans—perhaps as many as 6.0 billion—will live in that area by 2025. Many of the world's largest cities are situated in coastal areas, and these cities are currently growing more rapidly than noncoastal cities.

The United States is not immune to environmental destruction along its coasts. In fact, 14 of the 20 largest U.S. cities and 19 of the country's 20 most densely populated counties lie along coasts. These population statistics do not take into account the additional effects of seasonal visitors to coastal resorts. By 1997, 14% of U.S. coasts were developed, and the percentage is expected to rise to 25% by 2025.

ENVIRONEWS ON CAMPUS

Restoring Damaged Habitats

Regardless of your course of study in college, imagine getting the opportunity to minor in *restoration ecology* and work during your senior year with a student-faculty team to restore a nearby degraded site. Such an opportunity is available to students at the University of Washington (UW), which formed the interdisciplinary UW Restoration Ecology Network in 1999. Each year, faculty in the program meet with potential clients—such as local governments, schools, utilities, or community groups—to select an appropriate site for a year-long capstone project. Students participating in the project must have previously taken courses in restoration ecology and be familiar with how it links to their major field of study. Each student team is assembled from a variety of majors to provide interdisciplinary perspectives. Past projects have ranged from restoring riparian areas (stream banks) to controlling soil erosion to developing bird habitats. The capstone projects allow students to gain some real-world experience with ties to their academic majors.

Coastal management strategies must be developed that take into account projections of climate change, human population growth, and population distribution. Such comprehensive management plans will be difficult to formulate and execute because they must regulate coastal development and prevent resource degradation, both on land and in offshore waters. The key to successful planning is local community involvement. If the public understands the importance of natural coastal areas, people may become committed to the sustainable inhabitation of coastlines.

REVIEW

1. List at least five causes of wetlands destruction.

Conservation of Land Resources

LEARNING OBJECTIVE

- Name at least three of the most endangered ecosystems in the United States.

When wilderness was abundant, people did not observe or appreciate the many ecosystem services provided by forests, prairies, rangelands, and wetlands. Our ancestors considered natural areas as an unlimited resource to exploit. They appreciated prairies as valuable agricultural land and forests as immediate sources of lumber and eventual farmland. This outlook was practical as long as there was more land than people needed. But as the population increased and the amount of available land decreased, it became necessary to consider land as a limited resource. Increasingly, as we have come to understand the great value of ecosystem services, the emphasis has shifted from exploitation to preservation and restoration of the remaining natural areas.

Although all types of ecosystems must be conserved, several are in particular need of protection. The USGS Biological Resources Discipline and the Defenders of Wildlife commissioned studies that developed a numerical ranking of the most endangered ecosystems in the United States. They used four criteria:

1. The area lost or degraded since Europeans colonized North America
2. The number of current examples of a particular ecosystem, or the total area
3. An estimate of the likelihood that a given ecosystem will lose a significant area or be degraded during the next 10 years
4. The number of threatened and endangered species living in that ecosystem

Table 17.2 lists the 10 most endangered U.S. ecosystems based on these criteria. Examples include the south Florida landscape, southern Appalachian spruce-fir forests, and longleaf pine forests and savannas. As these ecosystems are lost and degraded, the organisms that compose them decline in number and in genetic diversity. Researchers have also found that some rare types of soils are threatened. Soils can take hundreds of years to develop but can be eroded very quickly when disrupted, threatening individual species that rely on these specialized soils. Conservation strategies

Table 17.2 The 10 Most Endangered Ecosystems in the United States

Ecosystems (in order of priority)
South Florida landscape
Southern Appalachian spruce-fir forests
Longleaf pine forests and savannas
Eastern grasslands, savannas, and barrens
Northwestern grasslands and savannas
California native grasslands
Coastal communities in lower 48 states and Hawaii
Southwestern riparian communities
Southern California coastal sage scrub
Hawaiian dry forest

Source: R. F. Noss, M. A. O'Connell, and D. D. Murphy. *The Science of Conservation Planning: Habitat Conservation Under the Endangered Species Act.* Island Press: World Wildlife Fund (1997). Reprinted with permission.

that set aside ecosystems are the best way to preserve an area's biodiversity (as well as its soil).

As discussed in this chapter, government agencies, private conservation groups, and private citizens have begun to set aside natural areas for permanent preservation. Such activities ensure that our children and grandchildren will inherit a world with wild places and other natural ecosystems.

REVIEW

1. What are three U.S. ecosystems that need protection?

ENERGY AND CLIMATE CHANGE

Native foods of the Amazonian Rain Forest

During the 21st century, both deforestation and global climate change will interact to affect the tropical rain forests of the Amazon River basin (Amazonia). As economic development proceeds in Brazil and other Amazonian countries, more forest will be converted to rangeland and cropland. This deforestation releases much of the carbon that had been stored in the trees into the atmosphere. Many plant and animal species that have traditionally been used as food sources will no longer grow wild.

REVIEW OF LEARNING OBJECTIVES WITH SELECTED KEY TERMS

- **Name at least four ecosystem services provided by natural areas.**

Natural areas provide many **ecosystem services**, including watershed management, soil erosion protection, climate regulation, and wildlife habitat.

- **Describe world land use.**

Globally, about 40% of the world's land areas are for human use (urban areas and agriculture); 30% are rock, ice, tundra, and desert; and 29% are natural ecosystems such as forests.

- **Describe the following federal lands and current issues of concern for each: wilderness, national parks, and national wildlife refuges.**

Wilderness is a protected area of land in which no human development is permitted. Problems in the **National Wilderness Preservation System** include overuse of some areas and the introduction of **invasive species**. National parks have multiple roles, including recreation and ecosystem preservation; problems include overuse, high operating costs, imbalances in wildlife populations, and development of lands adjoining park boundaries. The **National Wildlife Refuge System** contains habitat for the conservation of fishes, wildlife, and plants of the United States.

- **Define *sustainable forestry* and explain how monocultures are related to forestry.**

Sustainable forestry is the use and management of forest ecosystems in an environmentally balanced and enduring way. Sustainable forestry seeks to conserve forests for timber harvest, sustain biological diversity, prevent soil erosion, and preserve watersheds. A **monoculture** represents ecological simplification in which only one type of plant is cultivated over a large area; tree plantations that are monocultures have little species richness and are not a desirable practice for sustainable forestry.

- **Describe national forests and current issues of concern.**

National forests have multiple uses, including timber harvest, livestock forage, water resources and watershed protection, mining, recreation, and habitat for fishes and wildlife. Issues in national forests include confrontations over multiple uses, building logging roads with general tax revenues, and cutting old-growth forest.

- **Define *deforestation*, including clear-cutting, and describe the main causes of tropical deforestation.**

Deforestation is the temporary or permanent clearance of large expanses of forest for agriculture or other uses. Deforestation causes decreased soil fertility and increased soil erosion, impairs watershed functioning, contributes to the extinction of species, and contributes to regional and global climate changes. **Clear-cutting** is a logging practice in which all the trees in a stand of forest are cut, leaving just the stumps. **Tropical rain forests** and **tropical dry forests** are cut to provide temporary agricultural land, obtain timber, obtain open rangeland for cattle, and supply firewood and charcoal.

- **Explain how conservation easements help private landowners protect forests from development.**

A **conservation easement** is a legal agreement that protects privately owned forest or other property from development for a specified number

of years. In the **Forest Legacy Program**, the landowner grants a conservation easement to the U.S. government.

- **Describe public rangelands and current issues of concern.**

Rangeland is land that is not intensively managed and is used for grazing livestock. Provided the management of grazing animals is balanced with the rangeland's **carrying capacity**, the rangeland remains a renewable resource. About two-thirds of U.S. rangelands are privately owned; the federal government owns much of the remainder. The federal government allows private livestock operators to use public rangelands for grazing; environmental groups want public rangelands managed for other uses, such as wildlife habitat, recreation, and scenic value.

- **Define *desertification* and explain its relationship to overgrazing.**

Desertification is degradation of once-fertile rangeland or tropical dry forest into nonproductive desert. **Overgrazing** is the destruction of vegetation caused by so many grazing animals consuming the plants in a particular area that the land cannot recover. Overgrazing results in barren, exposed soil susceptible to erosion; if this **land degradation** continues, it contributes to desertification.

- **Discuss trends in U.S. agricultural land, such as encroachment of suburban sprawl.**

Agricultural lands are former forests or grasslands that were plowed for cultivation. Increasingly, agribusiness conglomerates farm large tracts of land and operate more cost-effectively than do family farmers on small pieces of land. In certain areas, agricultural lands are threatened by expanding urban and suburban areas.

- **Describe current threats to freshwater and coastal wetlands.**

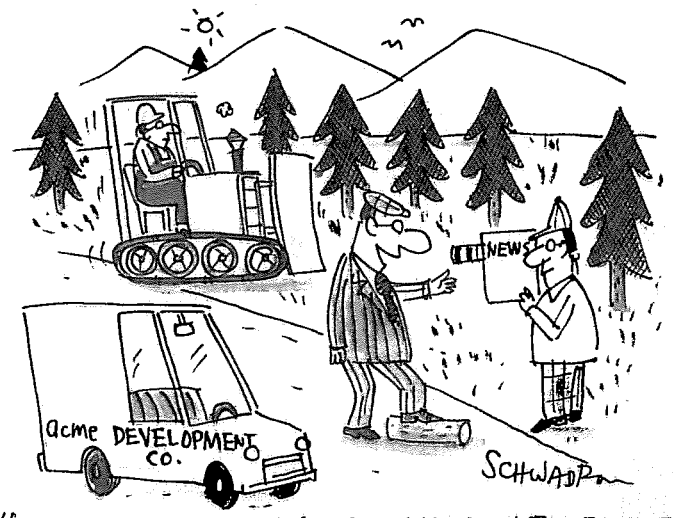
Wetlands are lands that are usually covered by shallow water for at least part of the year and that have characteristic soils and water-tolerant vegetation. Freshwater wetlands provide habitat for many organisms, purify natural bodies of water, and recharge groundwater. Despite their many ecosystem services, wetlands are often drained or dredged for other purposes, such as conversion to agricultural land. Coastlines include tidal marshes and other coastal wetlands. Ecosystem services provided by coastal wetlands include food and habitat for many wildlife species and protection from coastal erosion and storm damage. Failing to recognize the importance of coastal wetlands has led to their destruction and their development for residential and industrial purposes.

- **Name at least three of the most endangered ecosystems in the United States.**

According to the Biological Resources Discipline and the Defenders of Wildlife, the three most endangered ecosystems in the United States are the south Florida landscape, southern Appalachian spruce-fir forests, and longleaf pine forests and savannas.

Critical Thinking and Review Questions

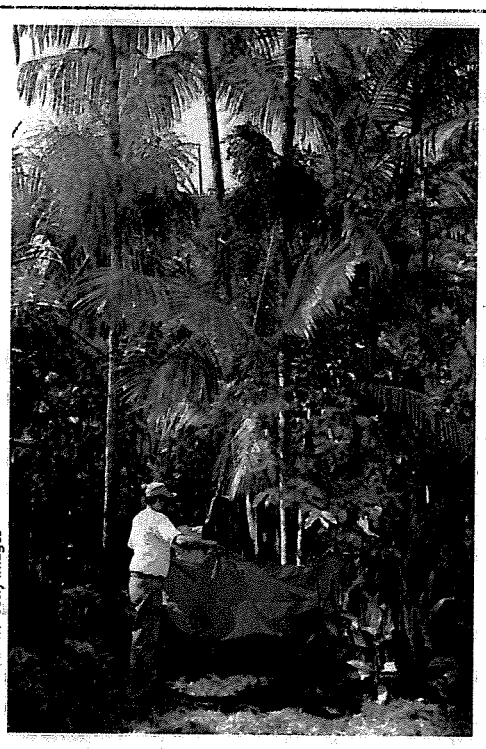
1. Name at least four ecosystem services provided by nonurban lands. Why is it difficult to assign economic values to many of these benefits?
2. What are the main types of federally owned land in the United States? What uses are permitted on each type of land? What are current issues of concern for each type?
3. Do you think additional federal lands should be added to the wilderness system? Why or why not?
4. Suppose a valley contains a small city surrounded by agricultural land. The valley is encircled by mountain wilderness. Explain why the preservation of the mountain ecosystem would support both urban and agricultural land in the valley.
5. How would you expect a park manager of a national park that adheres to natural regulation to respond to a lightning-induced forest fire? To the establishment of a noxious invasive weed species?
6. How does a healthy forest affect a region's hydrologic cycle? The carbon cycle?
7. Why is deforestation a serious global environmental problem?
8. What are four important causes of tropical deforestation?
9. What are the environmental effects of clear-cutting on steep mountain slopes? On tropical rain forest land?
10. Describe the Forest Legacy Program.
11. Distinguish between rangeland degradation and desertification.
12. Explain how certain tax and zoning laws increase the conversion of prime farmland to urban and suburban development.
13. What is a wetland? Why is the scientific definition of wetlands controversial?
14. What are three ecosystem services that wetlands provide?
15. Describe current wetlands protection policies in the United States and explain their strengths and weaknesses.
16. Should private landowners have control over what they wish to do to their land? How would you as a landowner handle land-use decisions that might affect the public? Present arguments for both sides of this issue.
17. Explain the irony in the following cartoon.



"WE BELIEVE WE WILL BE ABLE TO TEAR DOWN THE ENTIRE ECOSYSTEM IN AN ENVIRONMENTALLY FRIENDLY MANNER."

Food for Thought

Food plants from the Amazon rain forest include several plants that are familiar to us already: *açaí*, avocado, banana, coconuts, fig, grapes, lemon, mango, oranges, and pineapple. Others, like cupuaçu, a pulpy, white fruit with a fuzzy brown skin, are still unknown outside the region. How might our consumption of Amazon food plants support rainforest peoples? What kinds of problems might result from increased markets for rainforest food products?



Lew Robertson / Getty Images

Harvesting *açaí*.