Chapter 4

Land and Water Use

The Earth is comprised of continents and water resources, which are interrelated dynamic and complex systems. Humans depend on both systems for food, shelter, and resources that sustain our lives and economic structure. Land is used by people for agriculture, forestry, rangeland, and minerals, as well as for development, infrastructure, and recreation. Through fishing and aquaculture, water resources provide food, while minerals can be attained from the oceans. The resources provided from both land and water provide the basis of the global economic structure and its use is regulated through many laws and treaties.

Agriculture

One of the great challenges of humanity's transition from hunter-gatherer societies to cities was feeding a densely packed population. Now with the Earth's population pushing toward 7 billion, the challenge is greater than ever, requiring the development of efficient farming and livestock techniques. These techniques have so far allowed the food supply to keep pace with the population (though problems in markets and distribution leave many hungry millions). Still, agricultural science is not without its drawbacks including the potential for environmental damage. *Note:* The term *agriculture* applies to both crops and livestock, but this section focuses on farming of crops.

Feeding a Growing Population

Earth's human population is growing exponentially, from 1 billion people in 1800 to almost 2 billion in 1900 to 6 billion in 2000. More people require more food, and more food requires the use of more land, water, and fossil fuels, all of which impacts the environment.

Human Nutritional Requirements

Globally, the amount of food being produced per person has increased in modern times, and the ability to farm food has become faster and less work-intensive due to current technologies. Still, approximately 1.2 billion people do not get enough to eat on a daily basis and are considered undernourished according to the Food and Agriculture Organization of the United Nations. **Malnutrition** (in which people do not consume enough daily nutrients) and **undernourishment** (in which people do not receive enough calories) are worldwide issues, even with the modern abundance of food and reliability of food sources. The United Nations Commission on Human Rights estimates that every second, one person dies of starvation or hunger-related diseases. At the same time, others struggle with **over-nutrition** (receiving too many calories), which can lead to obesity and many related health issues.

Types of Agriculture

The practice of **agriculture** includes growing crops and raising livestock. The human practice of agriculture began about 10,000 years ago, following the period of the nomadic hunters and gatherers. At that time, humans began to cultivate crops, which required settling in one area to plant, tend, and harvest them. Along with this newly settled lifestyle, humans began raising livestock (and keeping domesticated animals including dogs). Crop agriculture that used human power, animal power, and simple tools is considered **traditional agriculture.** In its simplest form, traditional agriculture is conducted by a family for its own consumption and use. This is considered **subsistence agriculture,** in which enough food is created for the family but not for others. In contrast, agriculture on a large scale, with crop production for many people, and including the use of fertilizer, pesticides, irrigation, seeds, fossil fuels, monoculture (growing one single crop), and human power is considered **industrialized agriculture,** also called **conventional agriculture.** (For more information about industrialized agriculture, see the upcoming section "The Green Revolution.")

The Dust Bowl

Soil erosion, in which soil is transported from a location via wind or water, has an impact both at the site from which it was taken and the site at which it is deposited. Erosion is a natural process, but human intervention has led to its rapid increase to the point that we are losing nutrient-rich topsoil faster than it is created. One source of this erosion is the removal of trees and undergrowth to clear land for crops, rangeland, construction, and roadways. The roots of plants and trees are especially important as they trap soil and prevent wind and water from carrying it away. This erosion or other factors including overgrazing, drought, soil compaction, can lead to **desertification,** which is loss of soil productivity. In extreme cases, desertification can, as its name implies, lead to expansion of deserts and giant dust storms. Today, dust storms are common in areas of China and Africa, where the land has been overworked, but desertification also led to a dust storm in the United States that dated several years and devastated many states.

Due to the food needs of human expansion into the western United States in the late 1920s and early 1930s, natural land was cleared and replaced with crops and rangeland. The removal of vegetation, including grasses, trees, shrubs, and plants, exposed the soil to wind and water. To this newly overworked land, nature added a drought. This combination in the southern Great Plains, along with the stock market crash of 1929, led to the environmental, agricultural, and economic catastrophe known as the **Dust Bowl.** In hopes of averting another Dust Bowl, the United States created the Soil Conservation Act of 1935, the Soil Conservation Service (now the Natural Resources Conservation Service), and new guidelines for better farming practices.

The Green Revolution

The advent of industrialized agriculture in the mid- and late 20th century became known as the **Green Revolution.** This revolution included combining more effective farming techniques with the science of newly created crops to increase yields and efficiency. Developments during the Green Revolution included the following:

- High-yield crop varieties (mainly wheat, maize, and rice) created through breeding and crossbreeding techniques (selective breeding)
- Increased irrigation infrastructure
- Wide use of pesticides and fertilizers

The enormous benefit of the Green Revolution was the ability to produce more food on less land. Instead of feeding only the local population, crop excesses led to international markets in which food is exported and imported.

That said, more output requires more input. In the case of industrialized agriculture, inputs include fossil fuels for machinery and transportation, water, fertilizers, and pesticides. The environmental impacts of industrial agriculture can include pollution, contaminated waterways and drinking water, decreased available freshwater, reduced soil quality, and increased erosion, desertification, and salinization.

Another technique that became frequently used during the Green Revolution is **monoculture,** in which a field is planted with only one crop. Generally, monoculture makes planting and harvesting more efficient and, thus, more cost-effective. However, since a monoculture crop shares genetic makeup, the crop is at increased risk of decimation by one type of pathogen or pest. Also, monoculture allows fewer ecological niches, decreasing the potential for biodiversity. Without increased use of fertilizers, monoculture can deplete the soil of nutrients. Monoculture also is used in the livestock and aquaculture industries.

Genetic Engineering and Crop Production

Changing segments of an organism's DNA is called **genetic engineering** or **genetic modification,** and organisms that are altered are called **genetically modified organisms.** In the process of genetic modification, genes from an organism with a desired trait are harvested and spliced into the DNA of an existing organism. Ultimately, the

combination creates the desired traits (for example, increased growth rate, disease resistance, or size). The result of artificially transferring genetic material is known as a **transgenic organism.** Historically, the technique used to introduce desired traits in existing crops or livestock was selective breeding, but genetic modification differs in its altering of an organism's DNA; it might mix genes from different species with little or no similarities.

Here are some examples of genetically modified crops:

- **Golden rice:** Contains vitamin A, a missing nutrient in many developing countries
- **Ice-minus strawberries:** Frost resistant
- **Bt corn and cotton:** Contain insecticide, removing the need to spray chemicals
- **Long-lasting tomatoes:** Remain fresh longer

Generally, both sides of the genetic modification admit that genetically modified foods are entrenched in our food supply, for better or worse. Still, genetic engineering is a much-debated and highly emotional topic, with the basic points on both sides as follows.

Advantages and Disadvantages of Genetic Modification

Pros of Genetic Modification	Cons of Genetic Modification
The ability to feed more people with less energy, making farming more efficient	Unknown long-term effects on human health
The capability for foods to stay fresh longer, allowing them to be transported farther and have a longer shelf life	The ability for pests and weeds to grow resistance to the seeds containing built-in pesticides and herbicides, ultimately creating the need for more powerful products
The possibility to create foods resistant to weather extremes, which reduces the loss to the farmer and creates more consistent products and markets	The destruction of native, non-genetically-modified crops
The potential to develop foods containing nutrients missing in a local culture	The possibility of exacerbating allergies in people by creating either more products with the same allergen or a new allergen
The potential for improvements in medicine through development of new products	The unknowns of a new technology
The potential for seeds with built-in resistance to pests and weeds	The belief that, ethically, altering the food supply is not right
The potential to build crops that use less fertilizer and water	The fact that genetically modified seeds are patented, forcing farmers to purchase these seeds on an ongoing basis, which could lead to only a few companies having power over the entire global food supply

Crop Diversity

Our current food supply uses only a small sampling of existing crop types. Critics contend that this could make the agricultural industry susceptible to widespread devastation by an unforeseen event targeting one type of essential crop. One way to lessen this danger is by preserving diverse seed types, including wild varieties. For this purpose, **seed banks** exist throughout the world. Housing and preserving many seed types is a way to protect seed genetic diversity along with safeguarding our food supply in case of disaster.

Deforestation

Historically, in order to create land for agriculture, people have cleared forests and other land. While **deforestation** may have short-term benefits on food production, it has a negative and potentially disastrous effect on wildlife, ecosystems, and long-term human sustainability. Forests provide food, shelter, and habitat for an enormous variety of organisms; hold soil in place and reduce erosion; act as "carbon sinks," trapping carbon dioxide; and provide

resources for human use. Deforestation devastates ecosystems, reduces biodiversity, can destroy human populations, and has long-term global ramifications.

Irrigation

Supplying water for agricultural purposes is called irrigation. **Irrigation** allows areas that would otherwise be dry and unusable for agriculture to become fertile and productive. However, if land is over-watered, it can become **waterlogged,** a condition in which soil becomes saturated or oversaturated and the water table rises. This can ultimately suffocate plant roots, compact soil, and lead to salinization. **Salinization** occurs when salts accumulate on the soil's surface. When water evaporates from the soil's surface, it leaves behind the salts that were once dissolved in it. This salinization can reduce crop productivity. Salinization is more common in arid regions where there is limited precipitation, but it also can occur from over-irrigation and water logging.

Ways to reduce salinization include the following:

- Ensuring proper drainage
- Using only the necessary amount of water for irrigation
- Planting crops according to water need (not planting crops that require large amounts of water in areas with minimal natural water sources)
- Using low-salt irrigation water

Many modern irrigation systems use **drip irrigation,** which allows water to drip directly onto plants, as opposed to mass spraying of water onto an entire field. This increases water efficiency while reducing salinization.

Sustainable Agriculture

Some modern farmers use a variety of methods to reduce the environmental impact of growing crops, including conservation of soil, land, and water. Ironically, many of these methods were common in traditional agriculture, including the following:

- **No-till farming:** When farmland is only minimally disturbed while it is being prepared for crops. With conventional tillage, soil is plowed and turned, which can ultimately lead to soil erosion and soil compaction in the deeper layers. With no-till farming, more crop residue is turned back into the soil, reducing erosion and compaction.
- **Crop rotation:** The alternation of the types of crops grown on a piece of land from year to year or season to season. This regular change in crops allows nutrients to be returned to the soil and minimizes depletion of certain nutrients, such as nitrogen. It also helps to reduce the impact of insects and disease.
- **Intercropping:** Planting alternating crops throughout a field. Such diversifying reduces the impact of any single disease or crop-specific insects and can reduce erosion and nutrient depletion. This strategy also increases the diversity of crop yield on a single piece of land. In planning intercropping, it is important to use crops that do not compete with one another for nutrients, space, water, or sunlight.
- **Shelterbelts:** Created when tall plants or trees are planted along the edges of fields or farms to reduce the wind that creates soil erosion.
- **Contour farming:** Plowing rows across a hill, following the hill's contour lines. These rows of uniform elevation better trap water and reduce erosion.
- **Terracing:** Used on steep slopes of mountainous terrain. Often looking like steps, terraces are used to minimize erosion and retain water in areas otherwise unsuitable for planting crops. A well-known historic example is the terraces of the Inca ruins of Peru.

Only by using land sustainably can we ensure that land can be used indefinitely to provide a consistent and stable food supply. This includes conditions in which soils are not depleted of nutrients, water is used efficiently, crop diversity does not diminish, and rangeland is not overgrazed.

Sustainable agriculture tends to use resources in a more targeted, specific way. For example, drip irrigation directly waters where necessary and minimizes excess runoff. Fertilizer and pesticide use is replaced by natural, nonchemical products, or fertilizer and pesticides are used in efficient amounts instead of excessively. When no chemicals and only biological approaches are used, this is referred to as **organic farming.**

Controlling Pests

Humans consider many things to be "pests" (such as flies and bees), yet many insects are important to crop productivity. The difficulty for farmers has been fending off crop invaders while keeping the insects necessary for pollination and ecosystem balance.

Pesticides

The agricultural definition of the term *pest* includes insects, fungi, weeds, viruses, rodents, and other organisms that harm crops. Humans have developed synthetic chemicals and natural substances to control pests. As a whole, these substances are called **pesticides** but can be further categorized according to the organisms they are meant to kill. *Fungicides* are used to kill fungi, *herbicides* kill plants and weeds, and *insecticides* target insects.

Pesticides increase crop yields, decrease crop loss and failure due to pests, and can reduce the spread of disease (such as malaria) when they are used to kill certain types of insects (such as mosquitoes).

In addition to their intended use, however, pesticides can have detrimental effects:

- Pests evolve and develop resistance to pesticides over time (see below for additional information).
- Pesticides kill insects necessary for pollination.
- Many pesticides are toxic, especially in large amounts, and can harm humans and wildlife (see Chapter 6).
- Runoff from sites where pesticides are used contaminates water sources.
- Pesticides are expensive to use.
- Many pesticides are nonspecific and kill more than just the targeted organisms.
- Organism loss can alter entire ecosystems.

Pests evolve and develop genetic resistance to pesticides over time. When a pesticide is applied, most of the targeted organisms die, but some survive. The ones that survive then reproduce, passing on the genes that allowed them to survive. Over several generations, a population develops increasing resistance to the pesticide, forcing the use of more powerful pesticides to target these organisms. This creates a perpetual cycle of organisms developing resistance to pesticides and humans increasing our use of different and more powerful chemicals to control the pests.

Some pesticides have proven extremely harmful to the environment and to humans. For example, DDT (dichlorodiphenyltrichloroethane) was used as a pesticide in the United States until 1973, when it was banned due to its detrimental effects on the nervous systems of humans and wildlife. Some countries still use it, though, to control mosquitos and prevent the transmission of malaria.

Increasingly, farmers are exploring alternatives to synthetic pesticides, including oils from trees and plants, such as mint, clove, and rosemary. Also, farmers are using certain pesticides in a more targeted way for specific pests, resulting in less overall ecosystem destruction.

Integrated Pest Management

Another way to address the issue of pest control involves using more than one technique in a process known as **integrated pest management.** This process uses knowledge about the pest's life cycle and environmental interactions, with other control methods such as biological control, crop rotation, and chemicals when necessary. The goal of IPM is to reduce pest impact while also reducing pesticide use.

Livestock and Feedlots

Raising livestock is widely considered to be another essential part of feeding the human population. **Livestock** includes cows, chickens, pigs, goats, sheep, and other domesticated animals raised for profit. Commonly, animals such as cows are kept on large expanses of land to graze for a period of time until they are sold to feedlots. **Feedlots,** also called factory farms or concentrated animal feeding operations, are areas where livestock are fed foods high in energy to fatten them up before market. Feedlots require less land per cow and are a more efficient way of meeting the meat consumption needs of a large population. Also, the manure produced by feedlot animals is frequently used as fertilizer for farms.

Negative aspects of feedlots include potential contamination of water sources from runoff containing waste products and the increased potential for the spread of disease among animals in close contact, which necessitates use of antibiotics. This industry is monitored by states and federally by the Environmental Protection Agency, to help minimize the environmental impact.

The "Rangelands" section of this chapter discusses the environmental impacts of livestock agriculture on rangelands.

Forestry

The challenge of forestry is to balance humans' use of wood products with the importance of forests as ecosystems. Wood is used as fuel and provides the chief material for many products, including furniture, paper, packaging, and homes. Additionally, the timber industry is a major global resource, and many people depend on the jobs and income it creates. This necessitates finding a balance between human needs and ecological preservation.

Tree Plantations

Many timber companies are now planting fast growth species to most efficiently produce timber on land and maximize economic gain. These **timber plantations** are monocultural, with only one species being planted at a time. Since the trees are all planted and then harvested at the same time, they are all the same age, or **even-aged.** Once the trees are harvested, new seedlings are planted. Plantation forests have minimal diversity since the trees are all the same species, which limits the habitat they can provide for other organisms. However, timber plantations can potentially be used as a restoration strategy for previously degraded land, stimulating secondary growth.

Old Growth, Secondary Growth

Because of the extensive deforestation that has occurred globally and throughout the United States, many remaining forests are considered to be secondary growth. **Secondary growth** occurs when an original, **old-growth** forest is cut down and new growth emerges. Much of the original deforestation in the United States occurred soon after European colonization and subsequent westward movement, during which wood was used for building and fuel and land was cleared to make room for agriculture and development of homes and towns. Many of the forests have since been reforested with secondary-growth forests.

Currently deforestation continues on a grand scale in developing countries. The reason for extensive deforestation in these countries is the resulting economic gain—directly from the timber, from selling the rights for timber harvesting, or from the use of the land once it is cleared.

The negative consequences of deforestation include the following:

- Loss of species and biodiversity
- Release of excess carbon into the atmosphere, contributing to climate change
- Reduced conversion of carbon dioxide into oxygen in the process of photosynthesis
- Erosion of unprotected soils

- Depletion of soil nutrients
- Increased desertification
- Flow of effects through an ecosystem

Forest Fires

Forest fires are certainly destructive and can be dangerous, but they are also a necessary part of the forest ecosystem. Many ecosystems depend on fires to help seeds germinate and to return nutrients to the soil. For example, in a chaparral ecosystem, fire's extreme heat causes some species' seeds to open. Periodic fires also help to thin the underbrush in an ecosystem. Small fires that burn branches, twigs, and dead trees help to reduce a future fire's fuel, making a future fire less intense. However, if underbrush accumulates over a long period of time, as it did under the former Forest Service policy of fire suppression, the forest can be more prone to a larger, more devastating fire. Now, rather than suppressing fire, many areas use **prescribed burns** or **controlled burns** to help maintain forests.

Forest Management

Timber harvesting methods have improved their ability to keep ecosystems stable. Previously, timber was harvested only through **clear-cutting,** or taking all trees in an area and leaving nothing standing. This process destroys habitat and can lead to the issues of deforestation previously noted. When secondary growth does begin, if unmanaged, the new developing ecosystem can still be very different from the initial, native habitat. While clear-cutting is still used, other harvesting methods are gaining popularity.

Shelterwood systems leave a low number of full-grown trees in order to create shelter for emergent seedlings. Cutting is done on a regular basis with select tress taken each time. The mix of large and small trees provides continual coverage. In contrast, the **seed-tree** method leaves only mature and seed-producing trees standing, providing the seeds necessary for the regrowth of harvested trees. Both the shelterwood and seed-tree approaches are similar to clear-cutting in that many trees are taken and much of the land is left bare. With the **selection system,** though, most trees are left standing while only a few are harvested from an area at a time. This allows for uneven-aged stands of trees and reduces the impact on habitats and ecosystems.

National Forests

In the United States, the government has taken many actions to protect and preserve forest ecosystems. In 1905, the **U.S. Forest Service** was established to manage and conserve the nation's forests, with the goal of managing the timber resources for both use and ecosystem preservation. In response to the declining timber resources throughout the country, the **U.S. National Forest System** was created and is managed by the U.S. Forest Service. Also, the National Forest Management Act was passed in 1976 by the U.S. Congress, directing every national forest to have a resource management plan.

Australia, Canada, Brazil, India, Japan, the Philippines, and many other nations are working toward reducing deforestation as well. Also, in May 2010, at the Oslo Climate and Forest Conference in Norway, approximately 50 countries signed the REDD+ Partnership, aimed at reducing emissions from deforestation and forest degradation.

Rangelands

Rangelands are large expanses of undeveloped land containing primarily low vegetation such as grasses and shrubs, and are suitable for grazing of livestock. Throughout the world, cattle, goats, and sheep are necessary for the survival of many people and cultures, both for food and for the economic value of the animals. Commonly, these animals are grazed on rangeland. If not managed properly, though, these lands can become

overused and degraded, ultimately negatively impacting the local environment along with the people and animals that depend on the land.

Overgrazing

When vegetation on rangelands is over-consumed, it hinders plant regrowth. If the plants that are being eaten are not being replaced over time, the land becomes degraded and unusable. Consequences of overgrazing include the following:

- Soil erosion
- Soil compaction
- Desertification
- Proliferation of invasive species
- Reduction in biodiversity and native vegetation
- Economic loss to those who depend on the land, such as ranchers

When excessive vegetation is removed from the soil, the land is exposed to wind and water. Once soil starts to erode, it is more difficult for plant cover to regrow. The vegetation that does get a toehold in degraded rangeland consists mainly of invasive, weed-type plants, which livestock do not eat. The livestock also compact the soils with their weight and hooves; over time, the soil can become compacted enough that it is more difficult for water to seep through, blocking air from filling pore spaces, which roots need to grow. Once the consequences of overgrazing become visible, the cycle is hard to break, and each step creates more degradation of the land.

This cycle of degradation creating more degradation is called a *positive feedback loop,* in which, once the system starts moving in a direction, it accelerates in that direction unless an intervention stops the progression. This ultimately drives a system to an extreme. In this case, the extreme is degraded, unusable land.

Deforestation

Not all livestock is grazed on natural grassland. In some cases, forests are destroyed so local people can raise cattle and other livestock on the cleared land. The methods used to clear the land include slash and burn, in which entire sections of forest are cut down and burned. Sometimes grasses are then planted for livestock. In some countries, such as Brazil, the leading cause of deforestation is cattle ranching. For decades, governments, activists, businesses, and citizens have discussed deforestation due to its rapid rate of destruction and devastating effects such as biodiversity loss and ecosystem alteration. Forests, including rain forests, are cleared not solely for livestock use but also for crop production, timber, land rights, and tax incentives.

Luckily, people are increasingly learning the consequences of deforestation, so new and sustainable methods are being introduced and implemented in many places with the hope of saving natural forests and regenerating degraded land, while also continuing to raise livestock.

Desertification

The loss of vegetation and available water can lead to land degradation and, ultimately, desertification. Overgrazing is a major contributor to desertification, more so even than crop production. Contrary to popular opinion, land does not move toward desertification from drought only. Drought can exacerbate the problem, but overuse, deforestation, and climate change are the catalysts that create an area of land prone to desertification. Erosion born of deforestation and excessive use degrade the land, making it more difficult for the land to recover. Eventually, the land loses its ability to recuperate, especially in circumstances that are exacerbated by drought. Under these conditions, the land can become a desert. This is more common in arid or semiarid areas that do not receive large amounts of water on an annual basis. However, due to the large-scale deforestation of rain forests, even these water-rich, tropical regions have seen the desertification of the land that was once covered by lush vegetation and leaf litter. When a rain forest loses its trees, the soil is exposed to direct sunlight and dries out. With vegetation gone, roots and leaf litter are not available to hold the soil in place. This starts the process of desertification.

Rangeland Management

Grazing of cattle on rangeland can be sustainable when managed properly. Historically, in the United States, public lands have been open to grazing, and ranchers have been paid subsidies for their cattle to graze lands, so there has been little motivation to conserve. Now range managers control the use of rangeland by rotating use and continually monitoring carrying capacity of the land. This, combined with the creation of overgrazing laws and the efforts of ranchers to compromise with concerned parties, has led to more sustainable use of rangeland.

Internationally, the issue of overgrazing is even more dramatic, due to issues such as lack of available land. A variety of initiatives are used to support better land-use practices globally. For example, the Farmer-Centered Agricultural Resource Management Program (FARM) run by the United Nations helps farmers in eight Asian countries use proven sustainable farming practices. Also, in China the Farmland Protection Law (1994) mandates that businesses building on farmland create equal farmland in another area.

Conservation-Related Laws

Because of the serious soil depletion and erosion issues the United States has faced, laws have been enacted to protect this precious resource. In 1935, in response to the Dust Bowl, Congress enacted the Soil Conservation Act, which established the Soil Conservation Service to monitor soil erosion. Now called the Natural Resources Conservation Service, the agency has expanded to include water quality and pollution control.

Other conservation-related acts include the Food Security Act (1985), the Conservation Reserve Program (1985), the Taylor Grazing Act (1934), the National Environmental Policy Act (1969), the Endangered Species Act (1973), the Federal Land Policy and Management Act (1976), the Public Rangelands Improvement Act (1978), and the Federal Agriculture Improvement and Reform Act (1996). For more information about U.S. laws, please refer to Appendix D.

Other Land Use

While much human land use involves extracting resources, ecosystems are impacted by other human actions as well. The resources we harvest are used to develop and build products in a process that uses space, consumes resources, and creates waste. Increasingly, modern humans are exploring ways to do so sustainably.

Urban Land Development

As human society has shifted from a rural, agricultural society to an urban, industrialized society, land use has changed. Industrialization centralized many new jobs in urban areas, and since technological advancements also made agricultural processes more efficient, fewer people were needed to produce the needed food. This movement of people from rural to urban lifestyles is termed **urbanization.**

Increased manufacturing and the associated developments in technology, along with increasing population density in urban centers, have had both positive and negative consequences for the environment.

Advantages and Disadvantages of Urbanization

Benefits of Urbanization	Disadvantages of Urbanization
Increased sanitation	Increased air, water, and land pollution
Improved access to healthcare	Habitat destruction

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Benefits of Urbanization	Disadvantages of Urbanization
Easier access to a variety of resources and choices	Increased land use in urban areas
Increased job opportunities	Potential for "urban sprawl"
Use of public transportation and decreased use of individual transportation	More people per area of land
Ability to fulfill daily needs without traveling a great distance	Health issues
Centralized land use (less land use for a large number of people)	Reduced recreational space

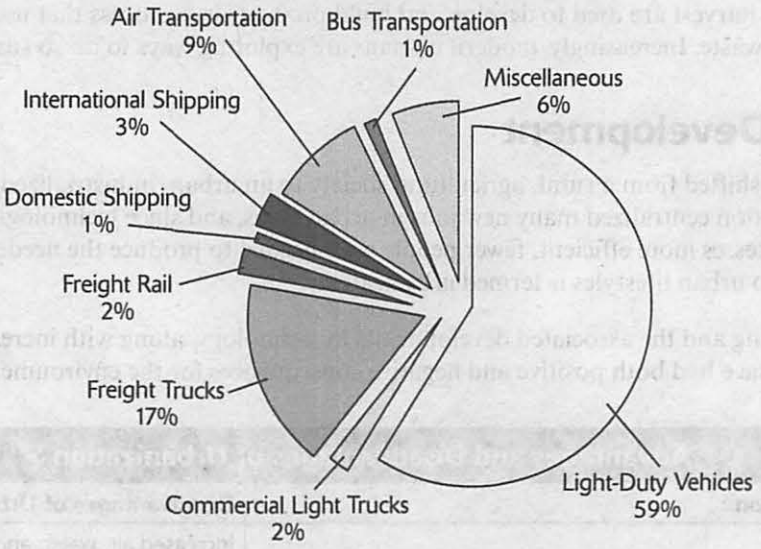
Transportation Infrastructure

Increasing populations and the globalization of our society necessitate the need for a larger **transportation infrastructure,** which encompasses the roads, rails, docks, gas stations, and additional framework that makes our transportation system possible. Common modes of modern transportation include automobiles, boats, trains, subways, and airplanes, all of which require a unique structure. All of our goods and resources are transported at some point in time, whether locally or internationally. Food must be transported from farms to processing centers to grocery stores and restaurants. Raw resources must be extracted and transported prior to manufacturing. After a product has been manufactured and packaged, it must be transported to a distribution warehouse and then finally to the store for purchase. And, of course, many people must travel to work, to school, to run errands, to see family and friends, and to enjoy recreational activities. In essence, almost every aspect of our modern world depends on transportation and, therefore, on transportation infrastructure.

Transportation and transportation infrastructure impact the environment, increasing air pollution by burning fossil fuels, destroying and fragmenting habitats, creating noise and light pollution, and increasing animal deaths due to collisions. However, since infrastructure is essential in today's world, instead of depending on decreasing infrastructure to lessen environmental impact, many point to thoughtful design and implementation of these systems as key to sustainable transportation.

A properly designed transportation system can effectively reduce the environmental impact of its use. For example, efficient highway systems can reduce the amount of time necessary for travel and can help to eliminate congestion. Reducing congestion reduces the amount of fuel needed and, thus, automobile emissions. Also reducing fuel consumption are urban transportation systems, such as subways and buses.

U.S. Transportation Fuel Usage



Source: EIA, Annual Energy Outlook 2008, Supplemental Table 36 (http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_36.xls).

Source: U.S. Energy Information Administration

U.S. Federal Highway System

The U.S. highway system began in 1944 with the Federal-Aid Highway Act, which approved the national system of highways. Then, in 1952, the Federal Highway Systems Act was passed, designating federal monies to help with the development of an interstate highway system. After years of debate over how the funds should be divided among the states, the Federal-Aid Highway Act of 1956 was passed, mandating, among other things, uniform highway design taking into account future traffic levels. These acts, combined with the efforts of Franklin D. Roosevelt and many others, gave rise to the existing interstate highway system.

Although this highway system drastically increased the ease of interstate travel, the environmental impact has been equally drastic, in large part due to the fragmentation of habitats. In hopes of lessening this fragmentation, today, before a highway can be constructed, an environmental impact statement (EIS) must be created to assess potential environmental impacts from the development.

Canals and Channels

Although less common than roadways, artificial waterways such as canals and naturally occurring waterways called channels still play an important part in the transportation of goods and services. A canal can be used to transport water for irrigation and human use, for recreation, and to control floods, as well as to transport people and goods.

A canal can be created by further digging and expanding an existing stream, creating a canal from dry land where no water source existed, or by developing a canal parallel to a stream or river. Canal size can vary from a small irrigation ditch in the Midwestern Unites States to the immense Panama Canal in Central America, to the series of canals in Venice, Italy. When canals are created, other waterways are affected, since the canal must be fed by a natural source of water. In some cases, canals are also dug into wetlands. This process alters the flow of natural waterways, removes vegetation, increases chances for erosion, and can lead to habitat fragmentation. Canals also can become contaminated from waste and runoff, leading to increased environmental degradation and threats to wildlife and human health. The modification of channels can lead to impacts similar to those of canal development. With increasing awareness of these issues and impacts, more effort is being made to keep canals healthy, minimize environmental impact, and properly plan the construction and use of canals and channels.

Public and Federal Lands

In the United States, land usage and the goals of land usage have changed, in part, due to human immigration and migration. During westward expansion, people explored and settled new areas, largely in the hopes of extracting and profiting from natural resources such as gold, silver, and timber. Laws created during these times including the Homestead Act of 1862 and the General Mining Act of 1872, focused on promoting the expansion and settlement of the country.

The federal government now manages about 29 percent of the land in the United States, which is overseen by four federal agencies: the Bureau of Land Management, the National Park Service and the Fish and Wildlife Service in the U.S. Department of the Interior, and the Forest Service in the U.S. Department of Agriculture.

Management

Created in 1905, the U.S. Forest Service manages public lands within national forests and grasslands. Originally it was established to provide water and timber for the nation, but its role eventually expanded to include the responsibility of managing all renewable resources found in national forests, including water, wildlife, wood, and recreation. The National Park Service, established in 1916, manages the nation's 394 national parks, preserving the wildlife, ecosystems, and historical value of the lands. In 1940, the Fish and Wildlife Service was created as a result of the merging of the Bureau of Fisheries and the Bureau of Biological Survey. This agency works to protect and conserve fish, wildlife, plants, and their habitats. The Bureau of Land Management was created in 1946, combining the General Land Office and the U.S. Grazing Service. Its mission is to protect resources and monitor resource use on public lands.

Gradually, the government's focus has shifted toward managing the increasing populations and establishing infrastructure and laws to support higher population densities while also protecting ecosystems and resources. In 1969, the National Environmental Policy Act was passed, and the law went into effect in 1970, mandating that environmental impacts be taken into account with any federal decision. The act also established the Council on Environmental Quality, requiring that an environmental impact statement be prepared for any action taken by a federal agency. Also established in 1970 was the Environmental Protection Agency (EPA), with the mission of establishing and enforcing environmental protection standards, gathering and using information pertaining to pollution, helping others through grants and other means to reduce pollution, and working with the Council on Environmental Quality to establish new environmental policies. Basically, the EPA writes and enforces regulations based on established laws pertaining to the environment.

Wetlands

Wetlands are terrestrial areas with water-saturated soils; they include marshes, swamps, and bogs. Found all over the world and in a wide variety of biomes, wetlands vary in vegetation, wildlife, water levels, nutrients, and many other factors, depending on the local environment. As one of the most productive ecosystems in the world (along with coral reefs and tropical rain forests), wetlands are an important component of our ecosystems, providing habitats for wildlife, recharging subsurface water supplies such as aquifers, filtering pollutants, preventing erosion of coastlines, and acting as flood control. A major human threat facing these important ecosystems is their destruction as a result of being filled in for agricultural use or for the development of buildings, roads, and other human uses. They are also threatened by high pollution levels, loss of vegetation, and alteration of water supplies. In the United States, many laws have been enacted to help prevent the destruction and loss of wetlands. These include the Clean Water Act, the Rivers and Harbors Act, and the Swampbuster provision in the Food Securities Act. Internationally, the Ramsar Convention on Wetlands of International Importance serves to protect wetlands and their resources. Extensive efforts are also being made to restore previously affected wetlands where possible.

Land Conservation Options

Numerous conservation efforts are being conducted at the local, regional, national, and global levels. **Conservation** focuses on managing land though sustainable use. In contrast, **preservation** takes the approach of no usage, attempting to completely eliminate human impact and to protect the valuable biodiversity and habitats of ecosystems. The choice of approach depends on individual circumstances, with most organizations and program managers taking the conservation approach.

U.S. Federal Programs

In the United States, various federal programs have been established to conserve and protect wildlife and ecosystems, including U.S. National Forests, U.S. National Grasslands, National Wildlife Refuges, and wilderness areas. Laws have also been created to help protect biodiversity; they are often amended to protect endangered species. Such laws include the Wilderness Act and the Endangered Species Act.

National Forests are United States federal lands, comprised mainly of forests and woodlands, which can be used by the public and for commercial use, including timber. This dual use has created much conflict, because the interests of the recreational and commercial uses are frequently at odds.

Similar to National Forests, **National Grasslands** have been established to conserve prairie grasslands. Grasslands are also used commercially for grazing and resource extraction, as well as recreationally for hunting and other recreation. National Grasslands are managed by the Department of Agriculture.

National wildlife refuges protect wildlife, fish, and vegetation, and seek to maintain ecosystem balance. Still, in many refuges, hunting and fishing are allowed, frequently to cull overpopulation, and for the revenue from hunting and fishing licenses, which helps to fund the protection and conservation of wildlife and the maintenance of the wildlife refuge system. The first national wildlife refuge was Pelican Island in Florida, designated as such in 1903 by President Theodore Roosevelt. There are now over 550 wildlife refuges and 38 wetland management areas, which are managed by the U.S. Fish and Wildlife Service.

As a result of the Wilderness Act of 1964 some federal lands were designated as **wilderness areas,** in which the land is relatively undisturbed and undeveloped by humans. These areas are considered part of the National Wilderness Preservation System and are managed by the Bureau of Land Management.

International Programs

Most international conservation efforts are overseen by the United Nations Environment Programme (UNEP), which promotes biodiversity and natural resource conservation on a global level. For example, the UNEP created the Convention on International Trade in Endangered Species of Wild Fauna and Flora to regulate international wildlife trade, helping to protect endangered and threatened species. The United Nations Convention on Biological Diversity was established to conserve biodiversity and to promote sustainability. The Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention) regulates migratory species, including avian, marine, and terrestrial organisms that cross national boundaries, conserving them throughout their migratory range.

Under the supervision of the International Union for Conservation of Nature, the World Commission on Protected Areas works toward the selection, establishment, and management of national parks and protected areas internationally, for the protection of plant and animal species. The organization works with governments and other key parties to plan and finance protected areas, including marine and terrestrial ecosystems.

Another approach to international preservation of terrestrial and coastal marine ecosystems is through the use of **biosphere reserves.** Operating under the World Network of Biosphere Reserves, these reserves combine the protection of biodiversity with sustainable land use, education, and scientific research. Each reserve is split into three, standardized zones: a central core area where there is almost no human activity, a buffer zone where there is limited human activity, and the transition zone in which a wide variety of sustainable human activities are allowed. Currently there are over 530 biosphere reserves globally.

Nongovernmental Programs

Nongovernmental organizations (NGOs) also play a large role in land conservation efforts. The Nature Conservancy is one of the world's largest NGOs working toward ecosystem conservation. The Sierra Club was founded in 1892 by John Muir to protect communities and wild places; it is the oldest and largest such organization in the United States.

Sustainable Land-Use Strategies

Advancements in sustainable building techniques help balance the needs of human society with environmental impact. Much of the policy governing sustainable building is designed at the city and regional levels. Effective city planning takes into account the location and types of parks and green areas, transportation infrastructure, recreation, commerce areas, housing options, hospitals, schools, energy usage, waste removal, and many other components. One way cities manage these diverse needs is through zoning (meaning that only certain types of building are allowed in certain areas). Zoning helps to control how a city grows and includes restrictions on what can be done with land, separating commercial, industrial, and residential areas.

Partly in response to congestion and high population density in cities, some people now choose to move out of large urban areas to surrounding suburban and rural areas, broadening the continued environmental issues associated with urbanization.

Mining

Humans use many minerals—such as copper, silver, cobalt, aluminum, nickel, tungsten, magnesium, lead, uranium, manganese, potassium, and many others—to manufacture the products necessary for everyday life. In order to obtain these minerals, the raw materials are mined from the layer of the Earth's crust called the lithosphere. People also extract resources such as limestone, gypsum, gravel, salt, and gemstones. Extraction processes can be very destructive to the environment and can have far-reaching impacts, especially due to the market-driven

need for companies to extract as much as possible as fast as possible and as cheaply as possible. However regulations exist to reduce environmental impact and help to conserve resources.

While the concept of mining applies to minerals and fossil fuels, this section addresses the mining of minerals. Fossil fuel formation and extraction are addressed in Chapter 5.

Mineral Formation

Minerals are nonrenewable resources formed through geologic processes. Most minerals are found not in their pure form but as an ore. An **ore** is a mixture of mineral elements packed together into naturally occurring molecular compounds. For example, galena is lead combined with sulfur (PbS) and is the most common form of lead found in nature.

Minerals can be formed through a variety of processes. Some minerals are formed when molten magma cools and the minerals it contains crystallize into deposits. Crystallization and, thus, mineral formation also can occur as water evaporates. Bodies of water contain dissolved minerals. When mineral-rich water evaporates, the minerals are left behind. Since oceans are high in salt content, much of the minerals left behind by evaporating water are salts. Minerals also can be formed as hot water cools. Minerals dissolve in hot water, but as water cools it can hold fewer minerals in solution. The excess crystallizes into mineral deposits. This crystallization due to cooling often occurs deep within the Earth and near hydrothermal vents in the ocean.

Mineral Extraction

The extraction of minerals is an invasive process that commonly has detrimental environmental impacts, such as the following:

- Habitat destruction due to the removal of vegetation
- Soil erosion
- Acid runoff from extraction processes, contaminating soil and water
- Air pollution as a result of fossil fuel combustion from machinery operations and smelting processes

Minerals and resources are extracted from the Earth in the following ways:

- **Surface mining:** Removes the soil and rock covering mineral deposits. This technique is used when deposits are located relatively close to the surface. Once the mineral deposit is completely extracted, the hole is commonly refilled with the original soil and rock.
- **Mountaintop removal:** When the tops of mountains are blasted off to access the resource. This technique is common in the coal mines of the Appalachian Mountains.
- **Placer mining:** Uses water to separate the heavier minerals from lighter mud and debris. This technique is commonly used to extract deposits found in riverbeds.
- **Open-pit mining:** Involves digging in order to reach the desired resource. Some pits are so large that the sides are terraced so that trucks can get in and out. Open pits are usually called quarries.
- **Subsurface mining:** Creates shafts deep underground to extract resources from pockets or seams of minerals. Dynamite blasts, drilling, and manual labor are used to remove rock and access the resource.

Impacts of Mining

	Impact	Common Use
Surface mining	Soil erosion, acid drainage*	Gravel, sand, coal, oil sands
Mountaintop removal	Deforestation, soil erosion, complete modification of local communities	Coal

	Impact	Common Use
Placer mining	Excessive debris in streams inhibiting biotic community, erosion of stream banks, loss of riparian habitat	Gems, gold
Open-pit mining	Complete ecosystem destruction, acid drainage*	Copper, iron, diamonds, gold, coal
Subsurface mining	Health hazards to miners, acid drainage*	Gold, copper, uranium, zinc, lead, nickel, coal, other metals

** Acid drainage occurs when sulfuric acid is created by the exposure of oxygen and water to sulfide compounds, which causes a reaction. This natural process is accelerated by the increased exposure of rock surfaces during mining processes. In some situations, the leakage from acid drainage could continue for hundreds of years and has the potential to filter into groundwater.*

While the specific negative impacts of mining techniques are noted in the table above, all mining processes cause habitat alteration and degrade ecosystems for the short term and potentially the long term. Ecosystem changes due to mining can include deforestation, soil removal, soil erosion, stream alteration, and the displacement of many organisms.

Mining Oceans

The ocean floor provides many resources, and the extraction of these resources is a relatively recent human endeavor. Sand, gravel, calcium carbonate, sulfur, phosphorites, silica, and valuable ores are all mined from the ocean bottom. **Manganese nodules,** a unique creation in the benthic environment, are ball-like structures created on the ocean floor. They contain manganese, along with many other minerals in smaller amounts, such as copper, zinc, and nickel. Mining of manganese nodules can be very destructive, as it disrupts and relocates large amounts of sediment. Also, the mining processes remove benthic organisms and can destroy structures on the ocean floor.

Mining Reclamation

Mining operations are destructive to the land, so the **reclamation,** or restoration, of the land after mining activities are completed can be a difficult and costly process. The process of reclamation varies depending on the type of mine, type of operations, location, and extent of environmental destruction. Metal mining can produce heavy metal and acid contamination, which can affect surface water and groundwater as well as potentially being toxic to humans and wildlife. With mining practices that disturb the surface of the land, it is not always possible to return the land back to its original state. One technique to restore land disturbed by mining is to replace lost topsoil with new topsoil reclaimed from agriculture.

Some mining sites are contaminated with hazardous wastes that require specialized cleaning techniques, as specified by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund. The cleanup of **Superfund** sites is the job of the federal government and paid for by a tax on the chemical and petroleum industries.

Mining Laws and Treaties

The General Mining Act of 1872 gives people the right to prospect on public lands, serving as the basis for further mining regulations. Mining operations also must comply with federal laws such as the Surface Mining Control and Reclamation Act (SMCRA); the Clean Water Act (CWA); the Clean Air Act (CAA); the Safe Drinking Water Act (SDWA); the Resource Conservation and Recovery Act (RCRA); CERCLA; and many others.

Since minerals are nonrenewable resources, sustainable use is an important aspect of managing them. This can be accomplished through recycling and reuse of products, as well as by thoughtful purchasing of products with the goal of reducing consumption.

Fishing

Throughout history people have fished Earth's oceans and freshwater sources. In modern times, however, these waters are being over-fished and depleted, mainly due to the use of techniques capable of harvesting large numbers of fish to meet the demand of our increasing global population. The excessive consumption of fish, combined with the destruction of aquatic habitats and ecosystems, has brought some fish populations close to extinction, with other populations declining rapidly, and many species are considered to be endangered or threatened. Ultimately, the balance of entire ecosystems and food webs can be dramatically altered by overfishing, with the potential for devastating ecosystem collapse.

Fishing Techniques

Modern fishing practices are designed to catch the most fish as quickly as possible and as cheaply as possible. As a result, these techniques tend to be both efficient and destructive. The three main industrial fishing techniques include bottom trawling, long-lining, and drift netting.

- **Bottom trawling** includes dragging a large net along the bottom to capture organisms. This can crush coral reefs and other organisms. It also can stir up sediment and decrease the amount of sunlight that reaches the deeper parts of the ocean. Other types of trawling target species that are either just above the benthic zone or in the pelagic zone (mid-ocean). Many nations have placed restrictions on when, where, or how trawling can be conducted.
- **Long-lining** involves dragging a long fishing line with baited hooks along its length behind a boat or attaching it to an anchor. Long-lining is used to catch surface fish such as swordfish or can be deployed closer to the ocean floor to catch benthic fish such as cod. One side effect of this fishing method is the high rate of bycatch, or fish and other organisms caught unintentionally while trying to catch a particular species of fish. Organisms commonly caught as bycatch include sea turtles and a variety of birds. Recently, the fishing industry has started making modifications to the lines in order to reduce bycatch.
- **Drift netting** is the practice of dragging large nets through the water to catch fish. The primary negative environmental impact of this technique is the large amount of bycatch, including sharks, dolphins, sea turtles, and whales. In some regions, the use of drift nets is regulated, with limits set on the size of the net. In other regions, this practice has been banned, either for particular species or altogether.

Overfishing

The extensive fishing of the oceans and freshwater sources allowed by large-scale commercial fishing methods has caused a dramatic decline in fishery numbers. Many fisheries are now collapsing, meaning the numbers are very low and continue to decrease. Because of the decline in populations of the larger, more desirable fish, fleets have started fishing the smaller, less desirable, less valuable fish. This process has been termed "fishing down the food chain," reflecting the literal change from harvesting larger fish, to medium-size fish, to smaller fish, similar to the progression down the aquatic food chain.

For years, fish harvest numbers remained stable, so many people assumed that the fisheries themselves were stable. But the fact is that population declines were simply balanced by developments in fishing techniques and technologies, including fishing in deeper waters, setting out more nets and lines, fishing for a longer period of time, traveling farther for the harvest, and using better technologies to locate the target. Not only does over-harvesting affect fishery populations, but it has economic impact on the individual, local, regional, and national scale.

Coral reefs

Very sensitive yet important aquatic ecosystems are coral reefs. Within the past half-century, though, these areas have been dramatically harmed by human activities, including pollution, harvesting of corals, acidification of the oceans, and water temperature changes. The changing aquatic environment around coral reefs has lead to a

process called coral bleaching, in which the microorganisms (called zooxanthalae) that live in a symbiotic relationship with coral leave the coral. The microorganisms provide food for the coral through photosynthesis, and the coral provides shelter for them. When the zooxanthalae leave, the coral loses its source of food and dies. It is considered "bleaching" because the microorganisms are the color in the coral, so when they leave, the color goes as well.

Aquaculture

As an alternative to fishing, humans have developed aquaculture to raise both freshwater and marine aquatic species in enclosed, monitored environments similar to farms on land. This helps to ensure continued and consistent fish products for consumption. Whether the farm is in a large, open-water floating pen or in ponds and tanks, there are environmental pros and cons to this newer form of agriculture. As with other human activities, if conducted on a responsible and regulated level, aquaculture can be sustainable.

Advantages and Disadvantages of Aquaculture	
Advantages	**Disadvantages**
Reduces bycatch	Increases risk of disease due to close proximity (monoculture)
Is energy efficient	Is associated with increased antibiotic use
Reduces consumption of wild populations	The fish may escape into the wild and could become invasive
Provides more reliable sources of food and protein	Results in excessive waste in a small area
	Some transgenic farmed fish are larger and faster than wild, so they outcompete them for resources.

Fishing Management

Historically, fishery conservation efforts were focused on individual species like salmon or swordfish, but this approach has proven to be largely unsuccessful. More recent management practices take an ecosystem-based approach, creating areas in the ocean that have limited or no human activity in hopes that the species will use these areas to restore themselves.

Fishing Laws and Treaties

There are numerous ways in which restrictions are made on fisheries at the state, federal, and international levels, including limits on the number of fish taken and pollution controls. Fishing regulations detail the species, amount allowed for harvesting per day, closed seasons, and other information specific to each type of fishery. Pollution regulations include the establishment of effluent limitation guidelines (ELGs), created to reduce pollutants from aquaculture wastewater released into open waters.

Major federal laws governing fisheries include the Marine Protection, Research, and Sanctuaries Act (MPRSA, also known as the Ocean Dumping Act); the Oil Pollution Act (OPA); the Clean Water Act; and the Endangered Species Act. International treaties include the United Nations Convention on the Law of the Sea (UNCLOS); the United Nations Fish Stocks Agreement; and the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported, and Unregulated Fishing.

With heightened conservation efforts and awareness, the use of more sustainable fishing methods and the enactment of laws, treaties, and regulations have helped to reduce bycatch and to reestablish some of the fishery populations that were previously in decline. However, there is still a long way to go in creating a sustainable fishing industry.

Marine-protected areas (MPAs) have been created to reduce fishing demands on marine organisms living within their boundaries. Still, most MPAs allow for some fishing and harvesting of marine life. Restrictions vary but can include bans on mining, extraction of resources, and the use of sonar. The size of the area included in an MPA also varies, from small to very large. Currently there are about 400 MPAs worldwide, in more than 65 countries. There is still a debate as to how useful MPAs are in protecting ecosystems and fisheries, but an increasing body of evidence demonstrates some progress in local fishery populations and ecosystem improvements due to MPAs.

A more restrictive type of MPA is a **marine reserve**, which does not allow human interference within the ecosystem and prohibits any activity that would remove or damage life in that area. This designation can help decimated fishery populations and ecosystems recover and/or remain stable. However, many people oppose the establishment of marine reserves, some citing the prevalence of locations in the oceans that are already off-limits to fishing and recreation.

Marine reserves demonstrate an increase in the following:

- Density of populations of organisms
- Biodiversity
- Biomass
- Organism size
- Larval supply

In both MPAs and marine reserves, there can be various levels of protection within the area, with some parts having to follow more stringent rules than others. There might also be seasonal restrictions. This multiple-use approach has the potential to meet the needs of fisheries and ecosystems, as well as humans who use the areas for economic and recreational purposes.

Global Economies

Globalization

The economy and the environment are interdependent. Not only do humans extract Earth's resources for use in making goods sold throughout the world, but this extraction and the services that support it provides jobs. The Earth's resources are the basis for the economy. Additionally, some have argued that without the economic need for Earth's resources, there would be reduced cause to preserve and protect them.

As human societies become more global, so does the economy and the use of resources. For example, a Japanese multinational company can buy rights to harvest timber in Canada and then export it for sale throughout the world. However, this globalization of resources can increase environmental damage because countries may not feel as much incentive to protect the ecosystems that house resources on the other side of the world.

Three ways in which the United States and other countries address the relationship between the environment and the economy are through the use of subsidies, green taxes, and permit trading:

- A **subsidy** is financial assistance given by the government to a business, a person, or an economic sector in an effort to support an activity that is thought to be beneficial to the public. Subsidies can be used to encourage sustainable activities such as energy conservation, research and development of new technologies, farming practices, and the production of fossil fuels. Unfortunately, there are often unintended negative consequences arising from the use of subsidies.
- **Green taxes** are placed on activities that are considered to be harmful to the environment. For example, the federal government has placed a tax on eight chemicals considered damaging to the ozone. Ultimately, this tax is frequently passed on to consumers, as companies increase the cost of their product to cover the cost of the tax.

- In **permit trading,** a maximum or "cap" is placed on the amount of pollution that an industry can emit, and individual companies are given permits for the amount they are allowed to pollute. If a company emits less pollution and, thus, does not need all its permits, it can sell the excess permits to another company that goes over its allotted amount of pollution. For example, a cap-and-trade system for carbon may help control the amount of carbon dioxide being released into the atmosphere.

World Bank

The World Bank was created in 1944 to help developing nations in need of financial and technical assistance in an effort to eliminate poverty. It provides loans, grants, and credits for activities deemed important to help a country reduce poverty and develop sustainable actions for working toward a more secure future. These activities frequently include agricultural, environmental, and natural resource management, education, health, infrastructure, finance, and public administration. The World Bank is made up of two separate institutions: the International Bank for Reconstruction and Development and the International Development Association. Examples of projects include the improvement and maintenance of roads in Argentina, the restoration of irrigation systems in Afghanistan, efforts to address India's energy shortage by laying power lines, and programs to treat and prevent malaria in Zambia.

In keeping with the mission to eradicate poverty and move toward more sustainable practices, the United Nations created the Millennium Declaration in 2000. One hundred and eighty-nine U.N. member states adopted it, making a pledge to eliminate poverty, increase development projects, and protect the environment.

Tragedy of the Commons

"The Tragedy of the Commons" is an essay written by Garrett Hardin in 1968. The essay's central point is that unregulated resources will eventually be overused and depleted, because although it is in the communal good to protect shared areas, it is in no individual's best interest to do so. To use economic terms, this "maximization of personal utility" means that each person's self-serving actions decreases the "utility" of the group in the long run.

Examples of these tragedies of the commons include the overharvesting of our fisheries in international waters, pollution of the air, and excessive use of underground water supplies. A well-known case study demonstrating a tragedy of the commons is the demise of Easter Island and its inhabitants. The native Polynesians overused the trees of the island, ultimately leaving their land devoid of timber, which had far-reaching impacts on their society and survival. (For additional discussion, see Appendix B.) Another common example is the overgrazing of cattle on public, unmonitored lands. Although it is in any one rancher's individual interest to exploit these lands to their fullest, with every rancher making this decision, the benefit of the shared resource is removed for all, as ultimately this practice does not allow for the regrowth of the grasses, leaving the land barren and ungrazable.

Global Economics Laws and Treaties

Making and enforcing international environmental laws and treaties can be difficult since many environmental issues cross national boundaries. There are over 1,000 treaties that pertain to the environment. Following are a few examples:

- The **Convention on Long-Range Transboundary Air Pollution** aims to gradually reduce air pollution, including trans-boundary pollution that travels over great distances.
- The **Convention for the Conservation of Antarctic Marine Living Resources** was established to protect marine life and ecosystems in and close to Antarctica. It is part of the Antarctic Treaty System.
- The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal** controls the transport of hazardous waste between nations, especially the transfer of waste from developed to less-developed countries. It also focuses on exemplary management practices and the reduction of toxicity of waste.

Practice

1. Which of the following is NOT a result of the Green Revolution?
   - A. Increased food production
   - B. High-yield crop varieties due to selective breeding
   - C. Decreased use of monoculture
   - D. More land being converted for use in agriculture
   - E. Use of pesticides and fertilizers

2. Deforestation, overgrazing, and the overworking of soil for crop production can lead to which of the following?
   - A. Salinization
   - B. Monoculture
   - C. Desertification
   - D. Increased crop rotation
   - E. Depletion of aquifers

3. Which of the following is an example of a project that would be supported by the World Bank?
   - A. Building commercial skyscrapers
   - B. Expansion of a shipping fleet
   - C. Development of military weapons
   - D. Purchase of land to be used as a hazardous waste site
   - E. Improvements in healthcare

4. What is the result of the suppression of forest fires?
   - A. Increase in succession in forest ecosystems
   - B. Severe fires when wildfires do occur
   - C. Increase in biodiversity in forest ecosystems
   - D. Abundance of soil nutrients
   - E. Strengthening of overall ecosystem health

5. Which of the following are issues that need to be addressed when planning for the reclamation of a mining site?
   - A. Acid drainage into water sources, loss of wildlife, erosion
   - B. Overpopulation of wildlife and over-accumulation of biomass
   - C. Desertification and salinization
   - D. Increase in eutrophication in local freshwater sources
   - E. Invasive species

6. Which of the following is associated with fishing down the food chain?
   - A. Harvesting of all fish species
   - B. The extinction of small fisheries
   - C. Harvesting of benthic organisms
   - D. Fishing for smaller and smaller fish due to the decline of larger fisheries
   - E. Selective breeding of fish species

7. Which of the following was the main driving force behind urbanization in the United States?
   - A. Better healthcare and education
   - B. Industrialization and technological advancements
   - C. Decline of the agricultural sector
   - D. Increased disease transmission
   - E. High levels of pollution in rural areas

8. Which of the following organizations is responsible for the management of public lands?
   - A. U.S. Forest Service
   - B. National Park Service
   - C. Congress
   - D. Bureau of Land Management
   - E. Environmental Protection Agency

9. Aquaculture has many benefits and many drawbacks. Which of the following is considered *a positive* aspect of aquaculture?
   - A. Decrease in disease among species of fish
   - B. Less waste in benthic environments
   - C. Reduction in fossil fuel use
   - D. Increased consumption of wild populations
   - E. Elimination of long-line fishing

10. Which of the following is one way to encourage businesses and people to use sustainable practices through monetary support?
   - A. A green tax
   - B. Marketable emissions permits
   - C. Subsidies
   - D. Laws and regulations
   - E. Imports and exports

11. Which of the following factors did NOT contribute to the Dust Bowl in the United States?
   - A. No-till agriculture
   - B. Removal of vegetation cover
   - C. Soil erosion
   - D. Desertification
   - E. Drought

12. The genetically engineered golden rice has been developed to do which of the following?
   - A. Resist the harm caused by frost
   - B. Provide vitamin A
   - C. Resist pests
   - D. Have long-lasting freshness
   - E. Produce more seeds

13. What is the role of the Comprehensive Environmental Response, Compensation, and Liability Act in relation to mining sites?
   - A. It mandates that mining activities must not change the contour of the land.
   - B. It states that mined land must be restored after the closing of the mine.
   - C. It sets limits on the amount of resources that can be harvested at any given time.
   - D. It established a tax-and-response process for hazardous waste.
   - E. It gives mining companies full control over the land on which they mine.

14. What is the goal of marine-protected areas?
   - A. Create areas where fishermen can fish without regulation
   - B. Establish a protected area in the ocean where resources are allowed to be extracted
   - C. Reduce stresses on fisheries by restricting some activities
   - D. Create zones for use in aquaculture
   - E. Eliminate fishing in the ocean altogether

15. Which of the following is a way city planning can reduce human impact on the environment?
   - A. Build efficient highway infrastructure
   - B. Create a downtown area that is spread out
   - C. Build zoos
   - D. Build directly on wetland areas to be close to the ocean
   - E. Eliminate recycling programs to reduce cost

Answers

1. **C** The use of monoculture increased during the Green Revolution. Large areas of land were converted for agricultural use, and new high-yield seed varieties became widely used. Monoculture is generally more efficient in planting and harvesting. The technological advancements during this time enabled new agricultural processes.
2. **C** Desertification is the loss of soil productivity due to erosion, overgrazing, drought, soil compaction, and any other factors that deplete the soil.
3. **E** The purpose of the World Bank is to help developing nations in need of financial and technical assistance in an effort to eliminate poverty. Therefore, an initiative to improve healthcare would be an initiative that the World Bank would undertake.
4. **B** Extended periods of fire suppression lead to increased fuel, mostly in the form of underbrush, causing the wildfires that inevitably occur to burn hotter and potentially consume more land. Forest fires naturally clear out dead brush, trees, and leaves, helping to keep the ecosystem clear of debris while returning nutrients to the soil. Also, many types of vegetation germinate after a fire because the seeds open from the extreme heat.
5. **A** Mining is a destructive process. Acid drainage can run off and contaminate freshwater and groundwater sources. Habitat alteration occurs to varying degrees in mining processes, with some techniques resulting in complete habitat destruction and others being less dramatic. This leads to loss of wildlife and biodiversity in the area of the mine. Also, the removal of vegetation leaves soil exposed and prone to erosion.
6. **D** Humans harvested the largest, most desirable fish to the point of drastically decreasing populations, forcing humans to then hunt for smaller fish, further down the food chain. As this process continues, smaller and less desirable fish are targeted. Basically, humans are "fishing down the food chain."
7. **B** As the country became industrialized, people started moving to city centers for jobs, healthcare, and education. The cities offered more opportunities and options.
8. **D** The Bureau of Land Management is responsible for the management of public lands.
9. **C** Because aquaculture farms are located close to shore and fishing fleets are not required to harvest the fish, fossil fuel use is reduced. In traditional fishing, boats may travel hundreds of miles for long periods of time to achieve their harvest goal. This consumes large amounts of fossil fuels and emits pollution.
10. **C** Subsidies are monies given by the government to people and companies in order to encourage certain desired practices.
11. **A** No-till agriculture does not cause soil disturbances like tillage agriculture does and can, thus, reduce soil loss due to erosion. A variety of factors contributed to the devastating impact of the Dust Bowl, including the clearing of land, overusing and overtilling for agricultural use, and drought.
12. **B** Golden rice was engineered to contain vitamin A, an important vitamin that some food supplies in developing or impoverished countries lack. This rice was developed as an aid toward addressing worldwide hunger.
13. **D** The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) established a tax on the chemical and petroleum industries and gave the federal government the authority to handle released hazardous substances or ones that have the potential to be released. Mining processes can use and produce acid, and heavy metals can contaminate water sources. These products are considered hazardous waste and must be dealt with in accordance with CERCLA regulations.
14. **C** Marine-protected areas (MPAs) have been created to conserve fisheries through the restriction of some activities such as mining and resource extraction. MPAs also have restrictions and limits on fishing and harvesting of various species.
15. **A** An efficient highway infrastructure can reduce the use of fossil fuels and emissions from vehicles because it will reduce the amount of time spent commuting from one location to another. If less time is spent driving, less fossil fuel is used and less emissions are produced.