Land and Water Use

CHAPTER 7

One does not sell the Earth upon which the people walk.
—Crazy Horse

FEEDING A GROWING POPULATION

In order to feed a population adequately, several factors must be taken into account. The following sections discuss these in detail.

Human Nutritional Requirements

A healthy diet generally requires 2,500 calories for the average male and 2,000 calories for the average female. Proper nutrition also requires a balanced intake of protein, carbohydrates, and fat. Protein produces 4 calories of energy per gram and should make up about 30% of all calories. Carbohydrates also produce 4 calories of energy per gram and should make up approximately 60% of the daily diet. Fats produce 9 calories of energy per gram and should not make up more than 10% of the total daily caloric intake.

Only about 100 species of plants of the 350,000 known are commercially grown to meet human nutritional needs. Of these, wheat and rice supply over half the human caloric intake. Just 8 species of animal protein supply over 90% of the world's needs. It takes about 16 pounds (7 kg) of grain to produce 1 pound (0.5 kg) of edible meat, and 20% of the world's richest countries consume 80% of the world's meat production. About 90% of the grain grown in the United States is grown for animal feed. By consuming the grain directly instead of consuming the animals that feed upon it, there would be a 20-fold increase in the amount of calories available and an 8-fold increase in the amount of protein available. The benefit of consuming meat products is that they are concentrated sources of protein that are broken down through digestion into amino acids.

In terms of famine and malnutrition, about 11 million children die each year from starvation, with 850 million people considered malnourished. Chronic undernourishment and vitamin or mineral deficiencies result in stunted growth, weakness, and increased susceptibility to illnesses.

Types of Agriculture

AGROFORESTRY

A system of land use in which harvestable trees or shrubs are grown among or around crops or on pastureland as a means of preserving or enhancing the productivity of the land.

ALLEY CROPPING

A method of planting crops in strips with rows of trees or shrubs on each side. Alley cropping increases biodiversity, reduces surface water runoff and erosion, improves the utilization of nutrients, reduces wind erosion, modifies the microclimate for improved crop production, improves wildlife habitat, and enhances the aesthetics of the area.

CROP ROTATION

Planting a field with different crops from year to year to reduce soil nutrient depletion. Example: Rotating corn or cotton, which removes large amounts of nitrogen from the soil, with soybeans which then add nitrogen to the soil.

HIGH-INPUT AGRICULTURE

Includes the use of mechanized equipment, chemical fertilizers, and pesticides.

INDUSTRIAL AGRICULTURE OR CORPORATE FARMING

A system characterized by mechanization, monocultures, and the use of synthetic inputs such as chemical fertilizers and pesticides, with an emphasis on maximizing productivity and profitability.

INTERCROPPING

To grow more than one crop in the same field, especially in alternating rows or sections.

INTERPLANTING

Growing two different crops in an area at the same time. To interplant successfully, plants should have similar nutrient and moisture requirements.

LOW INPUT

Depends on hand tools and natural fertilizers; lacks large-scale irrigation.

LOW-TILL, NO-TILL, OR CONSERVATION-TILL AGRICULTURE

Soil is disturbed little or not at all to reduce soil erosion. Has lower labor costs, reduces the need for fertilizer, and saves energy.

MONOCULTURE

The cultivation of a single crop.

ORGANIC FARMING

A form of agriculture that relies on crop rotation, green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control pests. This practice excludes or strictly limits the use of synthetic fertilizers, synthetic pesticides, plant growth regulators, livestock feed additives, and genetically modified organisms.

PLANTATION

A commercial tropical agriculture system that is essentially export oriented. The local government and foreign/international companies exploit the natural resources of the tropical rain forest for profit, usually short-term economic gain. It often involves the deliberate introduction and cultivation of economically desirable species of tropical plants at the expense of widespread replacement of the original native and natural flora. Plantation practices include modifications or disturbance of the natural landscape through such artificial practices as the permanent removal of natural vegetation, changes in drainage channels, application of chemicals to the soil, and so on.

POLYCULTURE

Polyculture uses *different* crops in the same space, in imitation of the diversity of natural ecosystems, and avoids large stands of a single crop (monoculture). It includes crop rotation, multicropping, intercropping, and alley cropping. Polyculture, though it often requires more labor, has several advantages over monoculture. The diversity of crops avoids the susceptibility of monocultures to disease. The greater variety of crops provides habitat for more species, increasing local biodiversity.

POLYVARIETAL CULTIVATION

Planting a plot of land with several varieties of the *same* crop.

SUBSISTENCE

Agriculture carried out for survival—with few or no crops available for sale. It is usually organic, simply for lack of money to buy industrial inputs such as fertilizer, pesticides, or genetically modified seeds.

TILLAGE

Conventional method in which the surface is plowed which then breaks up and exposes the soil. This is then followed by smoothing the surface and planting. This method exposes the land to water and wind erosion.

Green Revolution

The first green revolution occurred between 1950 and 1970. It involved planting monocultures, using high applications of inorganic fertilizers and pesticides, and the widespread use of artificial irrigation systems. Before the first green revolution, crop production was correlated with increases in acreage under cultivation. After the first green revolution, crop acreage increased about 25%, but crop yield increased 200%. Crop yield then reached a plateau since it was easier and more economical to increase crop production through various agricultural techniques than to buy and clear new land.

The second green revolution began during the 1970s and is continuing today. It involves growing genetically engineered crops that produce the most yields per acre. It is in contrast with past agricultural practices in which farmers planted a variety of locally adapted strains. For example, of all wheat grown in the United States today, 50% comes from 9 different genotypes.

CRITICISMS OF THE GREEN REVOLUTION

Critics cite the following as problems and/or failures of the Green Revolution:

- The Green Revolution is unsustainable.
- Increasing food production is not synonymous with increasing food security, i.e., famines are not caused by decreases in food supply but by socioeconomic dynamics and a failure of public action.
- Green Revolution agriculture produces monocultures of cereal grains, while traditional agriculture usually incorporates polycultures.
- There has been a drop in the productivity of land that has been intensively farmed for the past 30 years due to desertification and other forms of land degradation.
- The necessary purchase of inputs led to the widespread establishment of rural credit institutions, which then caused many smaller farmers to go into debt and in many cases resulted in a loss of their farmland.
- Green Revolution agriculture increases the use of pesticides, which are necessary to limit the high levels of pest damage that inevitably occur in monoculture.
- Salinization, water logging, and lowering of water levels in certain areas increased as consequences of increased irrigation.
- The Green Revolution reduced agricultural biodiversity, as it relied upon only a few high-yield varieties of each crop. This led to the susceptibility of the food supply to pathogens that cannot be controlled by agrochemicals, as well as the permanent loss of many valuable genetic traits bred into traditional varieties over thousands of years.

Genetic Engineering and Crop Production

Genetic engineering involves moving genes from one species to another or designing gene sequences with desirable characteristics. These include pest, drought, mold, and saline resistance, higher protein yields, and higher vitamin content. About 75% of all crops grown derive from genetically engineered or transgenic crop species.

CASE STUDY

Golden rice is produced by splicing three foreign genes, two from the daffodil and one from a bacterium, into a variety of rice that supplies vitamin A to populations that frequently suffer from vitamin A deficiency.

Genetically Engineered Crops

Pros	Cons
May require less water and fertilizer	Unknown ecological effects
Higher crop yields	Less biodiversity
Less spoilage	May harm beneficial insects
Faster growth which may mean greater productivity, resulting in lower operating costs	May pose allergen risk
More resistant to disease, drought, frost, and insects	May result in mutations with unknown consequences
May be able to grow in saltier soils	May cause pesticide-resistant strains

Irrigation

Three-quarters of all freshwater used on Earth is used for agriculture. Worldwide, approximately 40% of all crop yields come from 16% of all cropland that is irrigated. The use of irrigation depends on the climate and the degree of industrialization. For example, Canada irrigates about 10% of its crops, whereas India requires 90% of its crops to be irrigated. With inefficiencies such as seepage, leakage, and evaporation, up to 70% of all irrigation water can be lost. A drip irrigation system, which solves many of these problems but is more expensive to install, is used on approximately 1% of crops worldwide.

Increases in human population growth are outpacing the rate of land that is being irrigated. Sustainable irrigation is limited as a result of increases in costs, depletion of current sources of water, competition for water by urban areas, restoration of wetlands and fisheries, waterlogging, and salinization. Future water capacity will increase through increases in efficiency.

Sustainable Agriculture

Sustainable agriculture involves a variety of approaches. It integrates three main goals: environmental health, economic profitability, and social and economic equity. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs, and the individual grower's goals. Despite the site-specific and individual nature of sustainable agriculture, several general principles can be applied to help growers select appropriate management practices and are described below.

Changes in agriculture have had many positive effects and reduced many risks in farming. However, there have also been significant costs. Prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm laborers, increasing costs of production, and the disintegration of economic and social conditions in rural communities.

EFFICIENT USE OF INPUTS

Sustainable farmers maximize reliance on natural, renewable farm inputs with the goal to develop efficient, biological systems that do not need high levels of material inputs. Sustainable approaches are those that are the least toxic and least energy intensive and yet maintain productivity and profitability. Preventive strategies and other alternatives (such as integrated pest management) should be employed before using chemical inputs from any source.

SELECTION OF SITE, SPECIES, AND VARIETY

Preventive strategies, when adopted early, can reduce inputs and help establish a sustainable production system. When possible, pest-resistant crops should be selected that are tolerant of existing soil or site conditions. When site selection is an option, factors such as soil type and depth, previous crop history, and location (climate and topography) should be taken into account before planting.

SOIL MANAGEMENT

Proper soil, water, and nutrient management can help prevent some pest problems brought on by crop stress or nutrient imbalance. Furthermore, crop management systems that impair soil quality often result in greater inputs of water, nutrients, pesticides, and/or energy for tillage to maintain yields. In sustainable systems, the soil is viewed as a fragile and living medium that must be protected and nurtured to ensure its long-term productivity and stability. Methods to protect and enhance the productivity of the soil include using cover crops, compost, and/or manures, reducing tillage, and maintaining soil cover with plants and/or mulches. Regular additions of organic matter or the use of cover crops can increase soil aggregate stability, soil tilth and the diversity of soil microbial life.

SPECIES DIVERSITY

By growing a variety of crops, farmers spread out the economic risk and are less susceptible to the radical price fluctuations associated with changes in supply and demand. For example, in annual cropping systems, crop rotation can be used to suppress weeds, pathogens, and insect pests. Also, cover crops can have stabilizing effects on the agroecosystem by holding soil and nutrients in place, conserving soil moisture with dead mulches, and increasing the water infiltration rate and soil water-holding capacity. Optimum diversity may be obtained by integrating both crops and livestock in the same farming operation. Growing row crops on more level land and pasture or forages on steeper slopes will reduce soil erosion. Planting pasture and forage crops in rotation enhances soil quality and reduces erosion. Livestock manure, in turn, contributes to soil fertility. Livestock can buffer the negative impacts of low rainfall periods by consuming crop residue that in plant-only systems would have been considered crop failures. Feeding and marketing are flexible in animal production systems. This can help cushion farmers against trade and price fluctuations and, in conjunction with cropping operations, make more efficient use of farm labor and resources.

CONTROLLING PESTS

Pesticides can be used to control pests, but their use has drawbacks. Integrated pest management is another strategy to control pests.

Types of Pesticides

Pesticides differ in several ways. Their chemistry, how long they remain effective in the environment (environmental persistence), and their effect on the food web (bioaccumulation and biomagnification) are just a few concerns. Others include what type of organisms are affected, how the pesticides work (nervous system, reproductive cycles, blood chemistry), how fast they work, and their application.

BIOLOGICAL

Living organisms are used to control pests. Examples include bacteria, Bt (*Bacillus thuringiensis*), ladybugs, milky spore disease, parasitic wasps, and certain viruses.

CASE STUDY

Bacillus thuringiensis (Bt) is a soil-dwelling bacterium that also occurs naturally in the gut of caterpillars of various types of moths and butterflies, as well as on the dark surface of plants. Proteins produced by Bt are used as specific insecticides. It works by secreting one or more toxins after being ingested by an insect. The toxins are often specific to a family of insects, and because of their specificity, these pesticides are regarded as environmentally friendly. Advantages of using Bt include:

(i) The level of toxin can be very high, thus delivering sufficient dosage to the pest.
(ii) It is contained within the plant system; therefore only those insects that feed on the crop perish.
(iii) It replaces the use of synthetic pesticides in the environment.

A possible drawback to Bt may be that constant exposure to a toxin creates evolutionary pressure for pests resistant to that toxin.

CARBAMATES

Carbamates, also known as urethanes, affect the nervous system of pests. 100 grams of a carbamate has the same effect as 2,000 grams of a chlorinated hydrocarbon such as DDT. Carbamates are more water soluble than chlorinated hydrocarbons, which brings a greater risk of them being dissolved in surface water and percolating into groundwater.

CASE STUDY

Potato growers on eastern Long Island, New York, used Aldicarb (a carbamate) from 1975 to 1979 to control the Colorado potato beetle and the golden nematode. In 1979, Aldicarb residues were detected in well water. Subsequent testing found more than 2,000 wells with concentrations in excess of the New York State health standard. Aldicarb was banned from use on Long Island after 1979. Studies in 1983 and 1984 showed Aldicarb contamination in Long Island wells had increased in areas with a deep water table (about 30 meters). About 1,400 wells are still contaminated above state guidelines. Aldicarb's chemical characteristics make leaching to groundwater likely, as it is highly water soluble and is persistent in the environment. Since the contamination of the New York wells were first reported, Aldicarb has been found in the groundwater in 26 other states.

CHLORINATED HYDROCARBONS

Chlorinated hydrocarbons are synthetic organic compounds that affect the nervous system of pests. They are highly resistant to decomposition and can remain in the ecosystem for up to 15 years or longer. During the 1950s, DDT was linked with the thinning of eggshells in certain species of birds, such as the bald eagle.

FUMIGANTS

Used to sterilize soil and prevent pest infestation of stored grain.

INORGANIC

Broad-based pesticides. Includes arsenic, copper, lead, and mercury. Highly toxic and accumulate in the environment.

ORGANIC OR NATURAL

Natural poisons derived from plants such as tobacco or chrysanthemum.

ORGANOPHOSPHATES

Extremely toxic but remain in the environment for only a brief time. Examples include malathion to control mosquitoes and West Nile Virus, and parathion.

Costs and Benefits of Pesticide Use

Despite the use of pesticides, many pests worldwide have increased in numbers. This is due to genetic resistance, reduced crop rotation, increased mobility of pests due to increased world trade, and reduction in crop diversity. The following table shows the pros and cons of pesticide use.

The Pros and Cons of Pesticides

Pros	Cons
Kill unwanted pests that carry disease	Accumulate in food chains
Increase food supplies	Pests develop resistance and create a pesticide treadmill
More food means food is less expensive	Estimates range from $5 to $10 in damage done to the environment for every $1 spent on pesticides; pesticides are expensive to purchase and apply
Newer pesticides are safer and more specific	Pesticide runoff and its effect on aquatic environments through biomagnification
Reduces labor costs	Inefficiency—only 5% of a pesticide reaches a pest
Agriculture is more profitable	Threatens endangered species and pollinators; also affects human health

Integrated Pest Management

Integrated pest management (IPM) is an ecological pest control strategy that uses a variety of methods. When used in combination, these methods working together can reduce or eliminate the use of traditional pesticides. The aim of IPM is not to eradicate pests but to control their numbers to acceptable levels. In integrated pest management, chemical pesticides are the last resort. Methods employed in IPM include:

- Polyculture
- Intercropping
- Planting pest-repellent crops
- Using mulch to control weeds
- Using pyrethroids or naturally occurring microorganisms (such as Bt) instead of toxic pesticides
- Natural insect predators
- Rotating crops often to disrupt insect cycles
- Using pheromones or hormone interrupters
- Releasing sterilized insects
- Developing genetically modified crops that are more insect resistant
- Regular monitoring through visual inspection and traps followed by record keeping
- Construction of mechanical controls such as traps, tillage, insect barriers, or agricultural vacuums equipped with lights

RELEVANT LAWS

Federal Insecticide, Fungicide and Rodenticide Control Act (FIFRA) (1947): Regulates the manufacture and use of pesticides. Pesticides must be registered and approved. Labels require directions for use and disposal.

Federal Environmental Pesticides Control Act (1972): Requires registration of all pesticides in U.S. commerce.

Food Quality Protection Act (FQPA) (1996): Emphasizes the protection of infants and children in reference to pesticide residue in food.

FORESTRY

Forestry involves the management of forests. Sometimes this involves planting new trees, and sometimes it involves fires.

Ecological Services

Forests are an important global reserve. The ecological services of forests include:

1. Providing wildlife habitats
2. Carbon sinks
3. Affecting local climate patterns
4. Purifying air and water
5. Reducing soil erosion as they serve as a watershed, absorbing and releasing controlled amounts water
6. Providing energy and nutrient cycling

Tree Plantations

Tree plantations are large, managed commercial or government-owned farms with uniformly aged trees of one species (monoculture). Trees may not be native to the area and may be hybrids (genetically modified). The primary use of plantation trees is for pulp and lumber. Pine, spruce, and eucalyptus are widely used due to their fast growth rates and can be used for paper and timber. Trees are harvested by clear-cutting. Short rotation cycles of 25–30 years or 6–10 years in the tropics are economically important factors. Just 5% of the world's forests are tree plantations, but they account for 20% of the current world wood production. In comparison, 63% of the world's forests are secondary-growth forests, and 22% are old-growth forests.

Annually, tropical tree plantations yield much more wood (25 m^3/hectare) than traditional forests (1–3 m^3/hectare). Some of the natural closed forests—7%—are being lost in the tropics due to land conversion to tree plantations. Tree plantations do not support food webs found in old-growth forests, and they contain little biodiversity. Decaying wood is absent, which provides a vital link in an old-growth forest. Conversion to tree plantations may result in draining wetlands and replacing traditional hardwoods. Newer techniques allow leaving blocks of native species within the plantation or retaining corridors of natural forest. The Kyoto Protocol encourages use of tree plantations to reduce carbon dioxide levels although carbon dioxide may eventually re-enter the atmosphere after harvesting.

Old-Growth Forests

Old-growth forests are forests that have not been seriously impacted by human activities for hundreds of years. Old-growth forests are rich in biodiversity. Old-growth forests are characterized by:

- Older and mixed-aged trees
- Minimal signs of human activity
- Multilayered canopy openings due to tree falls

- Pit-and-mound topography due to trees falling and creating new microenvironments by recycling carbon-rich organic material directly to the soil and providing a substrate for mosses, fungi (necessary for *in situ* recycling), and seedlings
- Decaying wood and ground layer that provides a rich carbon sink
- Dead trees (snags) that are necessary nesting sites for woodpeckers and spotted owls
- Healthy soil profiles
- Indicator species
- A fungal ecosystem.

Depletion of old-growth forests increases the risk of climatic change. Many old-growth forests contain species of trees that have high economic value but that require a long time to mature (mahogany, oak, and so on).

Forest Fires

Forests are unique in terms of their ecological significance and the number and frequency of forest fires. Current wildfire frequency in the United States is about 4 times the average of 1970–1986. The total area burned by current fires is about 7 times its previous level. The U.S. Forest Service has lengthened the wildfire season by 78 days. The change in wildfire frequency appears to be linked to annual spring and summer temperatures. Longer, warmer summers are documented with an increase in the number of forest fires. A correlation exists between early arrivals of the spring snowmelt in the mountainous regions and the incidence of large forest fires. An earlier snowmelt can lead to an earlier and longer dry season, which provides greater opportunities for larger fires. As forests burn, they release their stored carbon as carbon dioxide into the atmosphere, further compounding the problems of global warming. Another reason for the increase in forest fires is a change in fire management philosophy. Any naturally started fire on federal land that is not threatening resources (homes or commercial structures) is allowed to burn.

CROWN FIRES

Occur in forests that have not had surface fires for a long time. Extremely hot. Burn entire trees and leap from treetop to treetop. Kills wildlife, increases soil erosion, and destroys structures.

GROUND FIRES

Fires that occur underground and burn partially decayed leaves. Common in peat bogs. Difficult to detect and extinguish.

SURFACE FIRES

Burns undergrowth and leaf litter. Kills seedlings and small trees. Spares older trees, and allows many wild animals to escape. Advantages: burns away flammable ground litter, reducing larger fires later; releases minerals back into soil profile; stimulates germination for some species with serotinous cones (requires heat to open up and release the seeds, such as giant sequoia and jack pine); helps to keep pathogens and insects in check; and allows vegetation to grow in clearings that provides food for deer, moose, elk, muskrat, and quail.

METHODS TO CONTROL FIRES

Two methods are used to control forest fires: prevention and prescribed burning. Prevention involves burning permits, closing parts of the forest during times of the year when the number of visitors is high and during periods of drought, and educating the public. Prescribed burning involves purposely setting controlled surface fires and setting small, prescribed fires to thin out underbrush in high-risk areas. It requires careful planning and monitoring. Other strategies include allowing fires to burn themselves out and creating large, clear areas around structures.

Deforestation

Deforestation is the conversion of forested areas to nonforested areas. They are then used as grasslands for livestock grazing, grain fields, mining, petroleum extraction, fuel wood cutting, commercial logging, tree plantations, and urban sprawl. Natural deforestation can be caused by tsunamis, forest fires, volcanic eruptions, glaciation, and desertification. Deforestation results in a degraded environment with reduced biodiversity and reduced ecological services. Deforestation threatens the extinction of species with specialized niches, reduces the available habits for migratory species of birds and butterflies, decreases soil fertility brought about by erosion, and allows runoff into aquatic ecosystems. It also causes changes in local climate patterns and increases the amount of carbon dioxide released into the air from burning and tree decay. In addition to the direct effects brought about by deforestation, indirect effects caused by edge effects and habitat fragmentation can also occur.

Methods that are currently employed to manage and harvest trees include:

- **Even-age management**—Essentially the practice of tree plantations.
- **Uneven-age management**—Maintain a stand with trees of all ages from seedling to mature.
- **Selective cutting**—Specific trees in an area are chosen and cut.
- **High grading**—Cutting and removing only the largest and best trees.
- **Shelterwood cutting**—Removes all mature trees in an area within a limited time.
- **Seed tree cutting**—Majority of trees are removed except for scattered, seed-producing trees used to regenerate a new stand.
- **Clear-cutting**—All of the trees in an area are cut at the same time. This technique is sometimes used to cultivate shade-intolerant tree species.
- **Strip cutting**—Clear-cutting a strip of trees that follows the land contour. The corridor is allowed to regenerate.

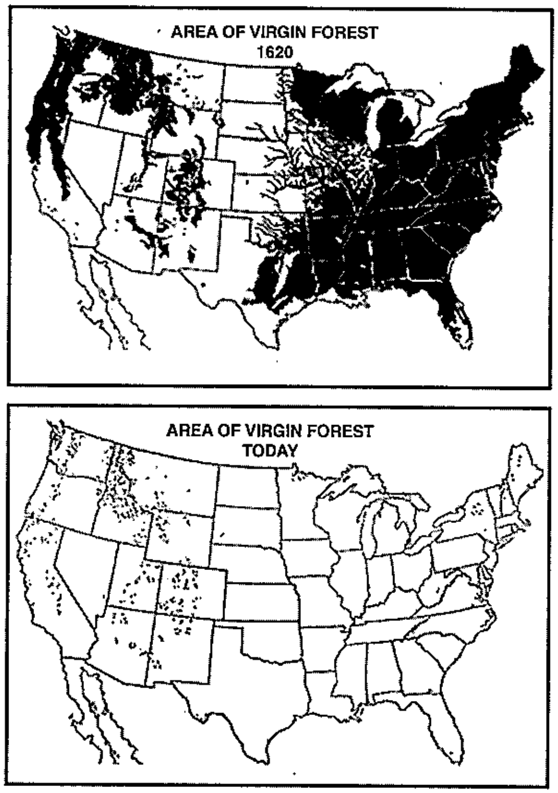

Figure 7.1 Deforestation in the United States (1620–present)

Deforestation alters the hydrologic cycle, potentially increasing or decreasing the amount of water in the soil and groundwater. This then affects the recharge of aquifers and the moisture in the atmosphere. Shrinking forest cover lessens the landscape's capacity to intercept, retain, and transport precipitation. Instead of trapping precipitation, which then percolates to groundwater systems, deforested areas become sources of surface water runoff, which moves much faster than subsurface flows. The faster transport of surface water can translate into flash flooding and more extreme floods than would occur with the forest cover.

Tree Plantations

Pros	Cons
Practical method for trees that require full or moderate sunlight in order to grow.	Reduces recreational value of land.
Efficient and economical method.	If done on steeply sloped areas, will often cause soil erosion, water pollution, and flooding.
Genetically improved species of trees that resist disease and grow faster can be grown.	Causes habitat fragmentation.
Increases economic returns on investments.	Reduces biodiversity.
Produces a high yield of timber at the lowest cost, and provides jobs.	Promotes monoculture and tree plantations that are prone to disease or infestation through the lack of diversity.

Deforestation also contributes to decreased evapotranspiration. This lessens atmospheric moisture and precipitation levels. It also affects precipitation levels downwind from the deforested area as water is not recycled to downwind forests but, instead, is lost in runoff and returns directly to the oceans. Forests are also important carbon sinks. Forests can extract carbon dioxide and pollutants from the air, thus contributing to biosphere stability and reducing the greenhouse effect. Forests are also valued for their aesthetic beauty and as a cultural resource and tourist attraction.

Three schools of thought exist with regards to the causes of deforestation—the impoverished school, the neoclassical school, and the political-ecology school. The impoverished school believes that the major cause of deforestation is the growing number of poor. The neoclassical school believes that the major cause is "open-access property rights." The political-ecology school believes that the major cause of deforestation is due to entrepreneurs.

CASE STUDY

The Hubbard Brook Experimental Forest centered on how deforestation affects nutrient cycles. The forest consisted of several watersheds each drained by a single creek. Impervious bedrock was close to the surface, which prevented seepage of water from one forested hillside, valley, and creek ecosystem to the other. Several conclusions were made. First, an undisturbed mature forest ecosystem is in dynamic equilibrium with respect to chemical nutrients. Nutrients leaving an ecosystem are balanced by nutrients entering the ecosystem. Second, inflow and outflow of nutrients was low compared with levels of nutrients being recycled within the ecosystem. Third, when deforestation occurred, water runoff increased. Consequently, soil erosion increased, which caused a large increase in the outflow of nutrients from the ecosystem. Increases in outflow of nutrients caused water pollution. Fourth, nutrient loss could be reduced by clearing trees and vegetation in horizontal strips. Remaining vegetation reduced soil erosion.

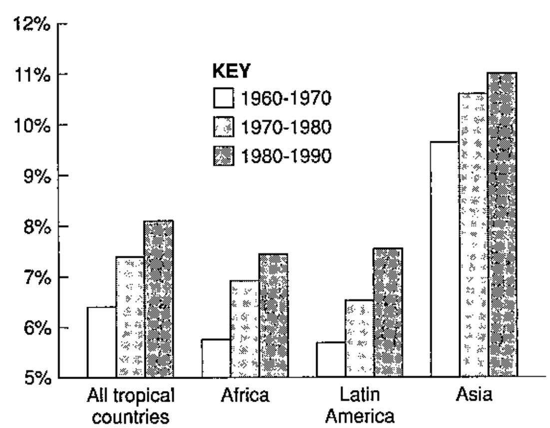

Figure 7.2 Rate of deforestation in tropical rain forests

Forest Management

Forests cover about one-third of all land surface worldwide. Most—80%—of these forests are closed canopies (tree crowns covering more than 20% of the ground), and 20% are classified as open canopy (tree crowns covering less than 20% of the ground surface). Most forests (70%) are located in North America, the Russian Federation, and South America. In the United States, the largest area of timbering is in the Pacific Northwest, employing 150,000 people and representing a $7 billion per year industry.

Forests account for about a third of the land in the United States, the largest of any land use category. Out of the 747 million acres of U.S. forest land, two-thirds (500 million acres) are nonfederal.

The Forest Service consists of 155 national forests and 22 grasslands, and it was established in 1905 as an agency of the U.S. Department of Agriculture. The Forest Service manages public lands in national forests and grasslands and encompasses 193 million acres (close to the size of Texas). These resources are used for logging, farming, recreation, hunting, fishing, oil and gas extraction, watersheds, mining, livestock grazing, farming, and conservation purposes.

The Forest Service protects and manages natural resources on National Forest System lands. It sponsors research on all aspects of forestry, rangeland management, and forest resource utilization. It provides community assistance and cooperation with state and local governments, forest industries and private landowners to help protect and manage nonfederal forests, associated ranges, and watersheds to improve conditions in rural areas. The Forest Service also provides international assistance in formulating policy and coordinating U.S. support for the protection and sound management of the world's forest resources.

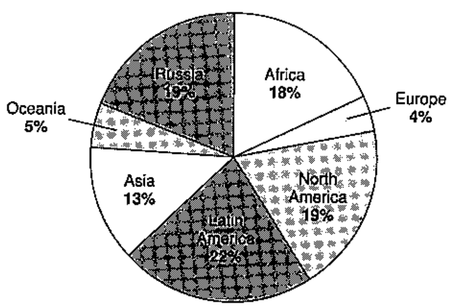

Figure 7.3 World forest distribution

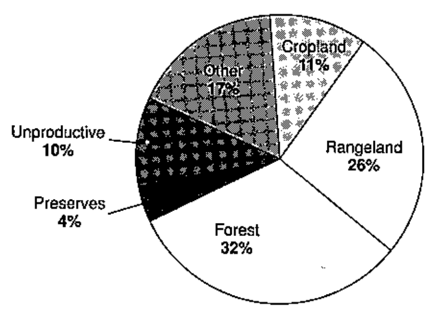

Figure 7.4 World land use

RELEVANT LAWS

Forest Reserve Act (1891): Gave the president authority to establish forest reservations from public domain lands.

Wilderness Act (1964): Created the legal definition of wilderness in the United States. Currently four agencies (National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, and the Bureau of Land Management) are in charge of more than 106 million acres (429,000 km^2) of federal wilderness.

Wild and Scenic Rivers Act (1968): Preserves and protects certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. Classified rivers as wild, scenic, or recreational.

Multiple Use and Sustained Yield Act (1960, 1968): Directs the U.S. Secretary of Agriculture to manage national forests for recreation, wildlife habitat, and timber production through principles of multiple use and sustained yield.

RELEVANT LAWS (continued)

Federal Land Policy and Management Act (FLPMA) (1976): Along with the Taylor Grazing Act, outlines policy concerning the use and preservation of public lands in the United States. Grants federal government jurisdiction on consequences of mining on public lands. Grants Bureau of Land Management (Department of the Interior) responsibility to manage all public lands not within national forests or national parks—a multiple-use policy.

Forest and Rangeland Renewable Resources Planning Act (FRRRPA) (1976): Also known as the National Forest Management Act. Requires the secretary of agriculture to develop a management program for national forest lands based on multiple-use and sustained yield principles. Also addresses timber-harvesting rates, methods, and locations.

National Forests Management Act (1976): Authorized the creation and use of a special fund in situations involving the salvage of insect-infested, dead, damaged, or downed timber and to remove associated trees for stand improvement.

Healthy Forest Initiative (2003): Allows timber companies to cut down economically valuable trees in most national forests for 10 years. Timber companies in return must clear out small, more fire-prone trees and underbrush. Law may have consequences of increasing fires by accumulation of slash and increasing the number of fire-prone, younger trees.

RANGELANDS

Rangelands are being compromised by overgrazing and desertification. The federal government is trying to manage and sustain the rangelanads.

Overgrazing

Overgrazing, which was the theme of the essay "The Tragedy of the Commons," occurs when plants are exposed to grazing for too long without sufficient recovery periods. When a plant is grazed severely, it uses energy stored in its roots to support regrowth. As this energy is used, the roots die back. The degree to which the roots die back depends on the severity of the grazing. Root dieback does add organic matter to the soil, which increases soil porosity, the infiltration rate of water, and the soil's moisture-holding capacity. If sufficient time has passed, enough leaves will regrow and the roots will regrow as well. A plant is considered overgrazed when it is regrazed before the roots recover. Overgrazing can reduce root growth by up to 90%.

Consequences to overgrazing include pastures becoming less productive, soils having less organic matter and becoming less fertile, and a decrease in soil porosity. The infiltration rate and moisture-holding capacity of the soil drops and susceptibility to soil compaction increases. Additionally, desirable plants become stressed, while weedier species thrive in these harsher conditions. Overgrazing causes biodiversity to decrease by reducing native vegetation, which leads to erosion. Riparian areas are affected by cattle destroying banks and streambeds, thereby increasing silting. Eutrophication increases due to cattle wastes. Therefore, aquatic environments are negatively impacted. Predator-prey relationships and the balance achieved through predator control programs are affected. Overgrazing increases the incidence of disease in native plant species. Finally, land is affected to the point where sustainability is threatened.