Publisher's Note

Salem Press is pleased to add *Principles of Ecology* as the fourteenth title in the *Principles of* series that includes *Modern Agriculture*, *Physics*, *Astronomy*, *Computer Science*, *Physical Science*, *Biology*, *Scientific Research*, *Sustainability*, *Biotechnology*, *Programming & Coding*, *Climatology*, and *Robotics & Artificial Intelligence*. This new resource introduces students and researchers to the fundamentals of ecology using easy-to-understand language for a solid background and a deeper understanding and appreciation of this important and evolving subject. All of the 110 entries included in the volume are arranged in an A to Z order, making it easy to find the topic of interest.

Entries related to basic principles and concepts include the following:

- Fields of Study related to the topic;
- Principal Terms and definitions;
- A Summary that provides brief, concrete summary of the topic and how the entry is organized;
- Text that gives an explanation of the background and significance of the topic to modern agriculture by describing developments such as Bacterial resistance; Brownfields; Carrying capacity; Deep ecology; Geoengineering, and Superfund legislations;
- Illustrations and tables that clarify difficult concepts via models, diagrams, and charts of such key topics as the Glacial melting, Greenhouse gas emissions; Groundwater pollutions, and hazardous wastes; and
- Further Reading lists that relate to the entry.

This reference work begins with a comprehensive introduction to climatology, written by volume editor Jennifer Heath.

The book includes helpful appendixes as another valuable resource, including the following:

- Timeline of American Environmentalism, tracing the field back to the limits and restrictions on cutting timber and hunting to the current administration's proposed cuts to environmental programs
- Key Figures in the areas of ecology and environmentalism, offering biographical information and a brief description of their contributions
- U.S. federal laws concerning the environment
- Directory of U.S. National Parks
- Major world national parks and protected areas
- Environmental organizations
- Bibliography
- Subject Index

Salem Press and Grey House Publishing extend their appreciation to all involved in the development and production of this work. The entries have been written by experts in the field. Their names and affiliations follow the Editor's Introduction.

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■ Accounting for nature

FIELDS OF STUDY

Agriculture; Biology; Culture; Ecology; Economics; Environment; Environmentalism; Forestry; Wilderness; Nuclear Technology

SUMMARY

In comparisons of the costs and benefits of various actions related to the environment, the coordination of ecological and economic expertise can result in a balanced problem-solving approach.

PRINCIPAL TERMS

- **biological wealth:** the natural species of all living things responsible for the structure and maintenance of all ecosystems and that sustains human life and economic activity
- **contingent valuation:** survey method used to estimate the value of non-market resources
- **cost benefit:** economic analysis assigning a numerical value to the cost-effectiveness of an operation, procedure, or program
- **debt for nature swap:** concept to deal with developing-nation indebtedness and its consequent deleterious effect on the environment, so that ameliorating debt could simultaneously promote conservation
- **globalization:** the process of interaction and integration among people, companies, and governments worldwide.
- **Gross Domestic Product (GDP):** the broadest quantitative measure of a nation's total economic activity, representing the monetary value of all goods and services produced within a nation's geographic borders over a specified period
- **net economic welfare:** proposed national income measure that attempts to put a value on the costs of pollution, crime, congestion, and other negative spinoffs to find a better measure of true national income
- **polluter pay principle:** commonly accepted practice that those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment

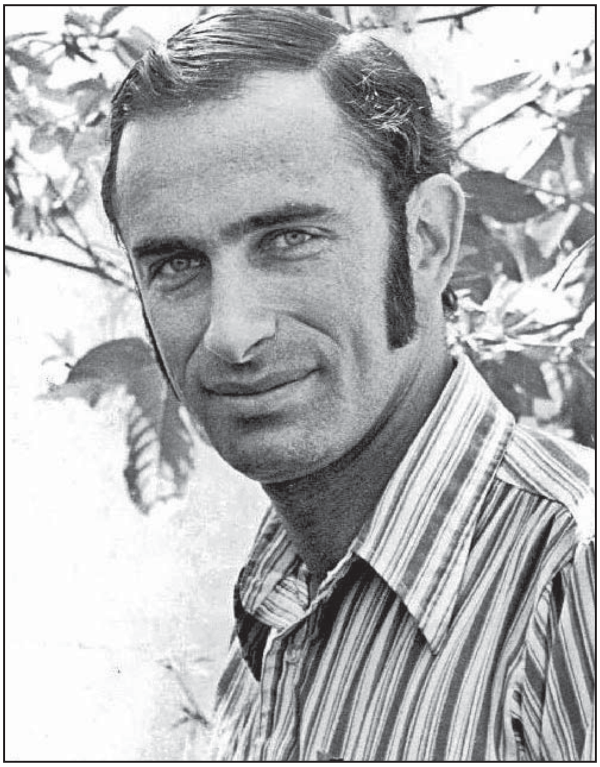

Photo of Dr. Paul R. Ehrlich, entomologist. By Ilka Hartmann (eBay).

Environmental decisions frequently set ecologists and economists on a collision course: Does society's demand for energy justify the environmental impacts of mining and burning coal? Is the increased economic efficiency of large corporate farms worth the loss of a rural lifestyle? How much should the public sacrifice to protect endangered birds or plants? These decisions are difficult because they force comparisons of “apples and oranges,” pitting one set of values against another. Quantitative models (or accounting systems) that compare the costs and benefits of a course of action are frequently used to guide business and government decisions, but these have generally omitted environmental values. Accounting for nature in these models cannot produce completely objective solutions but can help coordinate ecological and economic expertise in a more balanced problem-solving approach.

Ecologist Edward O. Wilson, among those who popularized the term “biodiversity,” has identified three kinds of national wealth: economic, cultural, and biological. He has observed that nations frequently create the illusion of a growing economy by consuming their biological or cultural “capital” to create short-term economic prosperity. For example, burning rain forests and replacing them with row crops may temporarily increase farm production in a developing nation, but tropical soils are often nutrient-poor and easily degraded by exposure to the sun and rain. If the biological basis of production is ignored, the population simply transfers wealth from one category to another, ensuring ecological disaster for its children in the process.

Developed nations have also neglected biological wealth in past cost-benefit analyses. Nations have justified the damming of wild rivers to make recreational lakes, for example, by counting the benefits of lumbering trees from the watershed but not the losses of aquatic and forest habitats. Recreational activities have been evaluated according to the money that people pay to participate in them; thus, hikers and canoeists in a wilderness area are given less consideration than water-skiers or drivers of recreational vehicles in a developed area because hikers and canoeists spend less money on equipment, fuel, and supplies.

Ecologists Eugene P. Odum and Howard T. Odum addressed this issue by calculating the value of ecosystem services provided by intact biological communities. Their approach was to measure the beneficial work performed by living systems and place a value on that service based on the time and energy required to replicate the service. A living tree, they reasoned, may provide a few hundred dollars in lumber if cut; if left alive, however, the oxygen it produces, carbon dioxide it absorbs, wildlife it feeds and shelters, soil it builds, evaporative cooling it yields, and flood protection it provides are worth far more on an annual basis.

National Wealth

In 1972, economists William Nordhaus and James Tobin refined the concept of national wealth by developing an index of net economic welfare (NEW) to replace the more familiar measurements of economic health such as gross domestic product (GDP). Their criticism of the GDP was that it counts any expenditure as a positive contribution to national wealth, whether or not the spending improves people’s lives. A toxic waste dump, for example, contributes to the GDP when the pollutants are produced, again when millions of dollars are spent to clean it, and yet again if medical costs rise because of pollution-related illness. Nordhaus and Tobin’s NEW index subtracts pollution abatement and other environmental costs from the value of goods and services that actually improve living standards.

Economist E. F. Schumacher subsequently argued that environmental costs should be “internalized,” or charged to the industries that create them. This idea, also called the “polluter pays principle,” not only generates funds for environmental cleanup but also encourages businesses to make environmentally sound decisions. The price of recycled paper, for example, would be more competitive if the public costs of deforestation and pollution from pulp mills were added to the price of virgin wood fiber. Proposals for internalizing environmental costs have ranged from centrally planned models, such as a carbon tax on fossil fuels, to free market trading of pollution credits. Debt-for-nature swaps, through which developing nations receive financial benefits for preserving natural ecosystems, represent environmental cost accounting on the asset side of the ledger.

A fundamental difference between economic and ecological worldviews is the time scale under consideration. Business strategies may look five years ahead, but ecological processes can take centuries. Thus, economic models that fail to take long-term issues into account are a frequent source of criticism by environmentalists. The U.S. decision to build nuclear fission reactors during the 1960s and 1970s is a case in point. Nuclear power appeared economically attractive over the thirty-five-year life span of a fission reactor, but the twenty-four-thousand-year half-life of radioactive plutonium 239 in spent fuel rods made skeptics wonder who would pay the costs of nuclear waste disposal for generations after the plants were closed.

Debates about growth are especially contentious. Traditional economists view the growth of populations, goods, and services as positive and necessary for economic progress and social stability. As early as 1798, however, economist Thomas Robert Malthus pointed out that on a finite Earth, an exponentially expanding human population would eventually run out of vital resources. In the closing decades of the twentieth century, Paul R. Ehrlich and Anne Ehrlich warned that unless population growth slowed soon, each person would have to consume less space, food, fuel, and other materials to avoid a global population crash. Whether one considers them economic pessimists or environmental realists, Malthus and the Ehrlichs demonstrate that taking a longer view is central to the task of accounting for nature. Sustainable development is the watchword for ecologists, economists, and political leaders attempting to create prosperity today while accounting for the welfare of future generations.

Contingent Valuation

Contingent valuation is used to assign value to nonmarket resources, such as renewable energy, open space, and sustainable development. While these resources provide utility, certain components of each do not have market prices; for example, renewable energy may reduce human-caused climate change or preserve fossil fuels for future generations. A contingent valuation survey is used to estimate a market price as a stated preference. The fundamental mechanism of the contingent valuation survey is asking people about their willingness to pay (WTP) to maintain an environmental feature or their willingness to accept (WTA) compensation for its loss.

Agricultural economist Siegfried von Ciriacy-Wantrup suggested the use of a direct interview method to measure the value of natural resources as early as 1947. Perhaps the first practical application was completed during the 1960s by economist Robert K. Davis, who measured the value of a specific wilderness area to hunters and recreationalists. Davis's contingent valuation results compared well with inferred value from cost associated with traveling to the wilderness area.

The method gained popularity during the 1970s in the United States as it was granted official recognition. Large numbers of studies were completed during the 1980s, with applications expanding to Europe and developing countries. However, criticism of the method also multiplied. Twenty-two expert economists on a panel convened in 1993 concluded that contingent valuation surveys must be carefully designed and controlled to ensure that valid results are obtained. They noted that individuals and organizations planning to employ contingent valuation should carefully review best practices before applying the method.

The panel offered specific recommendations concerning how contingent valuation surveys should be conducted, including the following. If possible, the survey interviews should be conducted in person; telephone surveys may be acceptable, but mail surveys should be avoided. A referendum format should be used in the questions; for example, "Would you be willing to contribute (or be taxed) D dollars to cover the cost of avoiding or repairing environmental damage X?" The results obtained from questions of this kind are more accurate than those gleaned from answers to open-ended questions, which are more likely to elicit strategic behavior, protest responses, biased answers, and incomplete consideration of personal income limits. The interviewers should ensure that respondents understand and accept the scenario they are asked to value. Respondents who do not accept the accuracy of the information concerning a scenario are in fact answering a question that is different from the one asked. Respondents should be reminded that their WTP for the specific scenario will reduce their ability to pay for other private or public goods.

Globalization

Globalization in the early twenty-first century rests on a free trade or neoliberal economic model that favors open markets and global competition among states and nonstate actors in the world economy. Intense competition among developing nations to secure investment and jobs from huge transnational corporations pushes ecological interests in those countries to the background of their political agendas. Corporate interests in the developed world tend to suppress movements for ecological reform that would cut into corporate profits.

Globalization is the subject of heated debate around the world, among politicians and economists as well as among scientists and environmental activists. From the standpoint of environmental ethics, globalizing trade practices have had devastating effects on the earth's natural environment. Regional neglect and the pollution of air, land, and ocean waters are driven by the "race to the bottom" phenomenon that pits developing countries against each other in efforts to lure global investors. Critics argue that the existing system is simply a broader-reaching, more profitable model of colonialism, a neocolonialism, whereby governments act as mere salespersons, promoting the profits of their corporations in a global marketplace.

Critics charge also that developing countries have no fighting chance in the global trade game, and so the rich get richer through the growing exploitation of the global poor and the devastation of the environment, in both the developed and the developing nations. Globalists, in contrast, assert that "free trade" promotes freedom and democracy, and that even as global inequality rises, poverty can be reduced through free trade. They argue that problems such as environmental degradation and global warming should be viewed as opportunities for entrepreneurial innovation and new economic ventures, and not as problems to be addressed through political intervention and legal restrictions.

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■ Agriculture

FIELDS OF STUDY

Agriculture; Agronomy; Biology; Ecology; Environment; Environmental Engineering; Food Science; Genetically Modified Food Production; Genetically Modified Organisms; Genetic Engineering; Horticulture; Horticultural Science; Land-use Management; Soil Science

SUMMARY

Agriculture is the ability to produce enough food and fiber to feed and shelter the population. Modern agriculture has exacerbated ecological damage adding a host of issues critical to the environment. The beginnings of agriculture predate written history, when, some eight to ten thousand years ago, humans discovered that seeds from certain wild grasses could be collected and planted and the grasses later gathered for food.

PRINCIPAL TERMS

- **agricultural chemical industry:** suppliers and manufacturers of fertilizers, insecticides, anthelmintics, mineral and vitamin supplements, pharmaceuticals, growth promotants, feed additives, sanitation materials; producers of much of agriculture's research, maintaining the data base of agricultural technical and scientific knowledge

- **assarting:** preparing fields by deforestation
- **genetically modified crops (GM):** plants used in agriculture, the DNA of which has been modified using genetic engineering methods generally in order to introduce a new trait to the plant not occurring naturally in the species. Also called biotech crops
- **Green Revolution:** term thought to have been introduced in 1968 describing the great increase in production of food grains due to the introduction of high-yielding varieties, to the use of pesticides, and to better management techniques
- **seminomadic farming:** seasonal migration when crops are cultivated during periods of settlement
- **slash-and-burn agriculture:** farming method involving the cutting and burning of plants in a forest or woodland to create a field called a swidden.
- **subsistence agriculture:** growing food crops for the survival of farmers and their families, with little or no surplus trade
- **swidden agriculture:** a technique of rotational farming in which land is cleared for cultivation, usually by fire, and left to regenerate. Also known as shifting cultivation

The earliest attempts to grow crops were primarily to supplement the food supply provided by hunting and gathering. However, as the ability to produce crops increased, people began to domesticate plants and animals, and their reliance on hunting and gathering decreased, allowing the development of permanent settlements in which humans could live. Six thousand years ago, agriculture was firmly established in Asia, India, Mesopotamia, Egypt, Mexico, Central America, and South America.

The first agricultural centers were located near large rivers that helped maintain soil fertility by the deposition of new topsoil with each annual flooding cycle. As agriculture moved into regions that lacked the annual flooding of the large rivers, people began to utilize a technique known as slash-and-burn agriculture, in which a farmer clears a field, burns the tress and brush, and farms the field. After a few years, soil nutrients become depleted, so the farmer must repeat the process at a new location. This type of agriculture is still practiced in some developing countries and is one reason tropical rain forests are disappearing at a fast rate.

In temperate climates, farmers often owned and lived on the land where they practiced swidden agriculture, clearing a portion of their land, burning the covering vegetation, growing grains for several years, then allowing that land to remain fallow, allowing the land and forests to recover. The slash-and-burn practice is not so much the problem as the length of a cycle. In some areas, land may require as little as five years to regain its maximum fertility; in others it may take one hundred years. Problems arise when growing populations pressure traditional farmers to return to fallow land too soon. Crops will be too small, leading to a vicious cycle in which the next strip of land is also farmed too soon, and each site yields less and less. As a result, more and more land must be cleared.

Another ancient form of agriculture, called nomadism, employs slash-and-burn techniques, but usually involves livestock rather than planting. Pressures generated by industrialized society are increasingly threatening traditional cultures of nomadic societies, such as the Bedouin of the Arabian Peninsula. Traditional grazing areas are being fenced off or developed for other purposes. Environmentalists are concerned about the ecological damage caused by nomadism. Wealth is measured by the size of a herd and herd animals eat increasingly large amounts of vegetation, which then has no opportunity to regenerate. Desertification may occur as a result.

Until the nineteenth century, most farms and ranches were family-owned, and most farmers practiced sustenance agriculture: Each farmer produced a variety of crops, enough to feed his or her family as well as a small excess sold for cash or bartered for other goods or services. Agricultural tools such as plows were made of wood, and almost all agricultural activities required human or animal labor. This situation placed a premium on large families to provide the help needed in the fields.

Land Clearance

Land clearance is the removal of plant life, stones, and other obstacles from a land surface to increase the area available for farming or construction of buildings. Although humans have modified land surfaces for food production and habitation since prehistoric times, the process of land clearance escalated tremendously from the mid-twentieth century onward, causing dramatic changes in ecosystems around the world. These changes have raised environmental concerns regarding soil, water, and air pollution and the loss of animal habitats.

Land clearance increased significantly when human beings transitioned from hunter-gatherer to agricultural societies. As agriculture developed, extensive land areas were cleared for crop growth. With the advancement of technology, the process of land clearance escalated as humans using heavy equipment became capable of not only rapidly clearing but also reshaping the landscape. Often, areas of cleared land that have become less productive than they were previously are abandoned in favor of newly cleared land that is more supportive of agricultural endeavors. These deserted areas often become barren wastelands devoid of human and animal habitation.

Modern Agriculture

The arrival of the Industrial Revolution changed agriculture, just as it did almost all other industries. Eli Whitney invented the cotton gin in 1793. The mechanical reaper was invented by Cyrus McCormick, and John Lane and John Deere began the commercial manufacture of the steel plow in 1833 and 1837, respectively. Steel, engines and mass production resulted in equipment that led the way to the development of the many different types of agricultural machinery resulting in the mechanization of most farms and ranches.

With the steel plow, humans began reshaping the Earth's surface, destroying native plants and wildlife habitats, so that many species were driven to extinction. One notorious result of large-scale plowing was the Dust Bowl of the 1930s. Without the roots of native plants to hold the soil down, a drought turned the loose soil into dust that literally buried entire towns.

By the early part of the twentieth century, most agricultural enterprises in the United States were mechanized. American society was transformed from an agrarian into an urban society. People left farms to go to cities to work in factories. At the same time, there was no longer a need for large numbers of people to produce crops. As a result, fewer people were required to produce the growing amounts of agricultural products that supplied an increasing number of consumers.

As populations continued to grow, there was a need to select and produce crops with higher yields. The Green Revolution of the twentieth century helped to make these higher yields possible. Basic information supplied by biological scientists allowed agricultural scientists to develop new, higher-yielding varieties of numerous crops, particularly the seed grains which supply most of the calories necessary for maintenance of the world's population. These higher-yielding crop varieties, along with improved farming methods, resulted in tremendous increases in the world's food supply.

Monoculture

The new crop varieties also led to an increased reliance on monoculture, crop specialization emphasized in modern agriculture. Farmers, especially in industrialized regions, often grow a single crop on much of their land. Problems associated with this practice are exacerbated when a single variety or cultivar of a species is grown. Such a strategy allows the farmer to reduce costs, but it also makes the crop, and thus the farm and community, susceptible to widespread crop failure. The corn blight of 1970 devastated more than 15 percent of the North American corn crop. The corn was particularly susceptible to harmful organisms because 70 percent of the crop being grown was of the same high-yield variety. Chemical antidotes can fight pests, but they increase pollution. Maintaining species diversity or varietal diversity—growing several different crops instead of one or two—allows for crop failures without jeopardizing the entire economy of a farm or region that specializes in a monoculture, such as tobacco, coffee, or bananas.

Genetic Engineering

Growing genetically modified (GM) crops is one potential way to replace post-infestation chemical treatments. Recombinant technologies used to splice genes into varieties of rice or potatoes from other organisms are becoming increasingly common. The benefits of such GM crops include more pest-resistant plants and higher crop yields. However, environmentalists fear new genes could trigger unknown side effects with more serious, long-term environmental and economic consequences than the problems they were used to solve. GM plants designed to resist herbicide applications could potentially pass the resistant gene to closely related wild weed species that would then become "super weeds." Also, just as pests can develop resistance to pesticides, they may also become resistant to defenses engineered into GM plants.

Erosion

An age-old problem, soil loss from erosion occurs all over the world. As soil becomes unproductive or erodes away, more land is plowed. The newly plowed lands usually are considered marginal, meaning they are too steep, nonporous or too sandy, or deficient in some other way. When natural vegetative cover blankets these soils, it protects them from erosive agents: water, wind, ice, or gravity. Plant cover "catches" rainwater that seeps downward into the soil rather than running off into rivers. As marginal land is plowed or cleared to grow crops, erosion increases.

Expansion of land under cultivation has not been the only factor contributing to erosion. Fragile grasslands in dry areas have also been used more intensively. Grazing more livestock than these pastures can handle decreases the amount of grass in the pasture and exposes more of the soil to wind, the primary erosive agent in dry regions. Overgrazing can affect pastureland in tropical regions, too. Thousands of acres of tropical forest have been cleared to establish cattle-grazing ranges in Latin America. Tropical soils, although thick, are not very fertile. After one or two growing seasons, crops grown in these soils will yield substantially less than before.

Tropical fields require fallow periods of about ten years to restore the soil after it is depleted. Thus, tropical farmers using slash-and-burn agriculture move to new fields every few years in a cycle that returns them to the same place years later, after their lands have regenerated. Where there is heavy forest cover, soils are protected from exposure to the massive amounts of rainfall. Organic material for crops is present if the forest remains in place. When the forest is cleared, however, the resulting grassland cannot provide adequate protection, and erosion accelerates. Lands that are heavily grazed provide even less protection from heavy rains, and erosion accelerates even more.

The use of machines also promotes erosion, and modern agriculture relies on machinery such as tractors, harvesters, trucks, balers, and ditchers. Machinery is used intensely in industrialized nations, and its use has been on the rise in developing countries such as India, China, Mexico, and Indonesia, where traditional, nonmechanized farming methods were previously the norm. Farming machines, in gaining traction, loosen topsoil and inhibit vegetative cover growth, especially when farm implements designed to rid the soil of weeds are attached. The soil is then more prone to erosion.

Eco-fallow farming has become more popular in the United States and Europe to reduce erosion. This method of agriculture, which leaves the crop residue in place over the fallow (nongrowing) season, does not root the soil in place as well as living plants do, so some erosion continues. Additionally, eco-fallow methods require the heavy use of chemicals, such as herbicides, to "burn down" weed growth at the start of the growing season. This contributes to increased erosion and pollution.

Pollution and Silt

Besides causing resistance among harmful bacteria, insects, and weeds, pesticides inevitably wash into surface and groundwater supplies, contaminating them. Pesticides are potentially harmful to human health; there has been concern that their seepage into land and water is linked to cancer.

An increasingly heavy silt load has been choking the life out of streams and rivers. Accelerated erosion from water runoff carries silt particles into streams, where they remain suspended and inhibit the growth of many forms of plant and animal life. The silt load in American streams has become so heavy that the Mississippi River delta has been growing faster than it once did. Heavy silt loads, combined with chemical residues, have been creating an expanded dead zone. By taxing the capabilities of ecosystems around the delta, sediments have been filtered out slowly, plant absorption of nutrients has decreased, and salinity levels for aquatic life have been unable to be stabilized. Most of the world's population lives in coastal zones, and 80 percent of the world's fish catch comes from coastal waters over continental shelves that are most susceptible to this form of pollution.

Pesticide Resistance

With the onset of the Green Revolution of the mid-twentieth century, the use of herbicides, insecticides, and other pesticides increased dramatically all over the world. An increasing awareness of problems caused by the overuse of pesticides followed, extending even to household antibacterial cleaning agents and other products. Mutations among the genes of bacteria and plants have allowed these organisms to resist the effects of chemicals that were toxic to their ancestors. The use of pesticides leads to a cycle wherein more or different combinations of chemicals are used, and more pests develop resistance to these toxins. Additionally, the development of herbicide-resistant crop plants enables greater use of herbicides to kill undesirable weeds on croplands.

Increasing interest in biopesticides (biological pesticides) may slow the cycle of pesticide resistance. Types of biopesticides include beneficial microbes, fungi, and insects such as ladybugs that can be released in infested areas to prey upon specific pests. Biopesticides may be naturally occurring or genetically modified organisms. Their use also avoids excessive reliance on chemical pesticides.

Fertilizers and Eutrophication

Increased use of fertilizers was another result of the Green Revolution. Particulate amounts of most fertilizers enter the hydrologic cycle through runoff. As a result, bodies of water become enriched by dissolved nutrients, such as nitrates and phosphates. The growth of aquatic plants in rivers and lakes is overstimulated, which results in the depletion of dissolved oxygen. This process of eutrophication can harm all aquatic life in these ecosystems.

Water Depletion

An increasing reliance on irrigation has contributed to the mismanagement and over tapping of groundwater resources. The rate of groundwater recharge is slow, usually between 0.1 and 0.3 percent per year. When the amount of water pumped out of the ground exceeds the recharge rate, it is referred to as aquifer overdraft. An aquifer is a water-bearing stratum of permeable rock, sand, or gravel.

In Tamil Nadu, India, groundwater levels dropped twenty-five to thirty meters during the 1970s due to excessive pumping for irrigation. In Tianjin, China, the groundwater level has declined 4.4 meters per year. In the United States, aquifer overdraft has averaged 25 percent over the replacement rate. The Ogallala aquifer—located under parts of South Dakota, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, Texas, and New Mexico—represents an extreme example of overdraft: the rate of depletion has annually been three times faster than its rate of recharge. The capacity of the aquifer decreased by an estimated 33 percent between 1950 and 2004. At this rate, the Ogallala aquifer, which supplies water to countless communities and farms, has been projected to become nonproductive by 2030.

Soil Salinization

In addition, continued irrigation of arid regions can lead to soil problems. Soil salinization has been widespread in the small-grained soils of these regions, which have a high water absorption capacity and a low infiltration rate. Some irrigation practices add large amounts of salts into the soil, increasing its natural rate of salinization. This can also occur at the base of a hill slope. Soil salinization has been recognized as a major process of land degradation.

Although surface and groundwater resources cannot be enriched by technology, conservation and improved environmental management can make the use of precious freshwater more efficient. In agriculture, for example, drip irrigation can reduce water use by nearly 50 percent. In developing countries, though, equipment and installation costs often limit the availability of these more efficient technologies.

Urban Sprawl

With the increasing mechanization of farms, the need for farmers and farm workers has been drastically reduced. From a peak in 1935 of about 6.8 million farmers farming 1.1 billion acres in the United States, for example, the country at the end of the twentieth century counted fewer than two million farmers farming 950 million acres. In 2012, the number of farm operations was at 2.17 million, according to the U.S. Department of Agriculture, with only 914 million acres of land in use.

Urban sprawl converts a tremendous amount of cropland into parking lots, shopping malls, industrial parks, and suburban neighborhoods. If cities were located in marginal areas, then concern about the loss of farmland to commercial development would be nominal. However, the cities attracting the greatest numbers of people have too often replaced the best cropland. Taking the best cropland out of primary production imposes a severe economic penalty.

Energy and Technological Efficiency

The increasing mechanization of farms has led to major increases in the amounts of energy consumed by these farms, particularly those in industrialized nations. Farms use large quantities of energy for irrigation, to operate machinery, to heat and cool buildings, for food processing and shipment, to spray pesticides, and to fertilize crops. The latter two are products of fossil fuels. Raising livestock on grain also consumes large quantities of fossil fuel. Large-scale livestock farmers often feed their animals grains and protein byproducts rather than employing traditional methods of foraging and consuming crop waste. Grain and protein byproduct feeding require less land and allows for the animals to grow to market weight quickly. However, this method of feeding can be inefficient, as animals convert only a fraction of their food energy into growth; for example, it has been estimated that seven kilograms of grain are needed to produce only one kilogram of beef.

Practices such as conservation tilling, which requires less working of the soil, have helped reduce energy use on farms. Another practice is drip irrigation, in which water drips slowly to the roots of plants, thus saving on both water and fertilizer. Farmers have also begun to plant genetically modified crops that do not need pesticide, which itself has become more sophisticated and therefore used in smaller quantities than before. Other farms have opted to grow organic (pesticide-free) food and to raise animals that are not given growth hormones and that are free-range, or not always confined in tight quarters. While these practices can be expensive, they can also save on energy costs and alleviate consumer concerns about ingesting potentially harmful chemicals.

Another way farmers have learned to save money on energy is to use renewable energy sources such as wind power, solar power, and biomass products (also called biofuel). By having electric wind turbines built on their farms, farmers can produce their own energy. Wind power can be used to power an entire farm or to power a specific area of the farm, such as pumping water for cattle. Solar energy can power a farm's lighting and heating (e.g., in greenhouses), pump water, and produce electricity. It can even be used to dry crops faster and more evenly than crops left prone to damage in the fields. Many farmers grow corn to make ethanol. Other crops have begun to be used for fuel as well, since there is virtually no limit to the type of plant and organic waste that can be used to produce energy. Agriculture creates a lot of waste; there is the potential for taking that waste and converting it into energy, thus saving on energy production costs, disposal costs, and pollution. Crops grown specifically for biofuel—for farms and other consumers—can be produced in large quantities and thus become profitable when sold.

Other technologies that have made farming become more efficient—and that have saved and made farmers money—are broadband Internet access, smartphones, and Global Positioning System (GPS) technology. Use of the Internet has helped farmers quickly exchange important data with each other and has helped farmers connect directly to their markets and consumers. GPS technology has helped farmers navigate their fields in a fraction of the time it took before this invention; equipment can be guided through fields, with no overlap or gaps, so that seeds can be planted, and pesticides sprayed evenly. Smartphone applications (apps) for crop scouting can help farmers identify a problem and its specific source immediately, eliminating the need to apply pesticide, for example, to an entire field in the hopes of rectifying that one problem. There are numerous other mobile applications useful to farmers as well.

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■ Air pollution and greenhouse gases

FIELDS OF STUDY

Atmospheric Sciences; Atmospheric Structure and Dynamics; Chemistry; Climate Change; Climatology; Ecology; Elements; Emissions; Environment; Environmentalism; Hazardous Materials; Industries; Meteorology; Pollution; Substances; Toxic Waste

SUMMARY

Greenhouse gases raise the Earth's average temperature 33 degrees Celsius (59 degrees Fahrenheit) above what it would be if these gases were not present in the atmosphere. Most scientists agree that human activities are contributing to increased concentrations of greenhouse gases and thus to increases in the average surface temperature of the earth.

PRINCIPAL TERMS

- **carbon dioxide**: a colorless, odorless, incombustible gas, CO2, present in the atmosphere and formed during respiration, usually obtained from coal, coke, or natural gas by combustion
- **fluorocarbons:** compounds characterized by great chemical stability, used chiefly as a lubricant, refrigerant, fire extinguishing agent, and in industrial and other applications in which chemical, electrical, flame, and heat resistance is essential, and banned as an aerosol propellant in the U.S. because of concern about ozone layer depletion.
- **global warming:** an increase in the earth's average atmospheric temperature that causes corresponding changes in climate and that may result from the greenhouse effect
- **greenhouse gases:** atmospheric gases that allow sunlight to reach the earth's surface but at least partially block infrared from radiating back into space
- **Kyoto Protocol:** an international treaty extending the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that global warming is occurring that it is extremely likely that human-made emissions have caused it

- **methane:** a colorless, odorless, flammable gas, CH4, the main constituent of marsh gas and the firedamp of coal mines, obtained commercially from natural gas
- **nitrous oxide:** a toxic reddish-brown gas NO_2, a strong oxidizing agent produced by combustion, as of fossil fuels, and is an atmospheric pollutant, as in smog
- **ozone:** a form of oxygen, O3, with a peculiar odor suggesting weak chlorine produced when an electric spark or ultra violet light is passed through air

National Ambient Air Quality Standards for Criteria Pollutants

Pollutant	Averaging Time	Pollutant Level	Effects on Health
Carbon monoxide: colorless, odorless, tasteless gas; it is primarily the result of incomplete combustion; in urban areas the major sources are motor vehicle emissions and wood burning.	1-hour 8-hour	35 ppm 9 ppm	The body is deprived of oxygen; central nervous system affected; decreased exercise capacity; headaches; individuals suffering from angina, other cardiovascular disease; those with pulmonary disease, anemic persons, pregnant women and their unborn children are especially susceptible.
Ozone: highly reactive gas, the main component of smog.	1-hour 8-hour	0.120 ppm 0.080 ppm	Impaired mechanical function of the lungs; may induce respiratory symptoms in individuals with asthma, emphysema, or reduced lung function; decreased athletic performance; headache; potentially reduced immune system capacity; irritant to mucous membranes of eyes and throat.
Particulate matter < 10 microns (PM10): tiny particles of solid or semisolid material found in the atmosphere.	24-hour Annual arithmetic mean	150 $\mu g/m^3$ 50 $\mu g/m^3$	Reduced lung function; aggravation of respiratory ailments; long-term risk of increased cancer rates or development of respiratory problems.
Particulate matter < 2.5 microns (PM2.5): fine particles of solid or semisolid material found in the atmosphere.	24-hour Annual arithmetic mean	65 $\mu g/m^3$ 15 $\mu g/m^3$	Same as PM10 above.
Lead: attached to inhalable particulate matter; primary source is motor vehicles that burn unleaded gasoline and re-entrainment of contaminated soil.	Calendar quarter	1.5 $\mu g/m^3$	Impaired production of hemoglobin; intestinal cramps; peripheral nerve paralysis; anemia; severe fatigue.
Sulfur dioxide: colorless gas with a pungent odor.	3-hour 24-hour Annual arithmetic mean	0.5 ppm 0.14 ppm 0.03 ppm	Aggravation of respiratory tract and impairment of pulmonary functions; increased risk of asthma attacks.
Nitrogen dioxide: gas contributing to photochemical smog production and emitted from combustion sources.	Annual arithmetic mean	0.053 ppm	Increased respiratory problems; mild symptomatic effects in asthmatics; increased susceptibility to respiratory infections.

Note: ppm equals parts per million and $\mu g/m^3$ equals micrograms per cubic meter.
Source: United States Environmental Protection Agency (EPA); URL http://www.epa.gov.

Airborne particulate matter represents a complex mixture of organic and inorganic substances and varies in size, composition, and origin. Some are known as primary particles, emitted directly from sources such as construction sites, unpaved roads, fields, smokestacks, and fire. Secondary particles are formed by reactions of gases, such as sulfur dioxide and nitrogen oxides, that are emitted from power plants, industrial plants, and automobiles, as well as dust, dirt, soot, and smoke, large enough to be visible to the naked eye, although other forms are so small, they require electron microscopes for detection. The inhalation of microscopic particles can have serious adverse effects on human respiratory and cardiovascular health.

Most scientists accept that a small global warming has taken place—that is, the earth's surface temperature has warmed about 0.7 degree Celsius (1.3 degrees Fahrenheit)—since the end of the nineteenth century. At least half of this temperature rise is attributed to the release of greenhouse gases into the atmosphere by human beings. It is thought that if greenhouse gases were returned to their 1990 levels, the temperature would still rise another 0.5 degree Celsius (0.9-degree Fahrenheit). Since greenhouse gases are transparent to visible light, sunlight passes through the atmosphere and warms the earth's surface. The warmed surface radiates infrared into the sky, where greenhouse gases absorb infrared and then reradiate it. They radiate about half of the infrared upward into space and half of it back down to the earth's surface. Since the earth absorbs more energy than it radiates back into space, it heats up until the energies entering and leaving are equal. Balance is possible because a hotter earth radiates with greater intensity and at shorter wavelengths where greenhouse gases allow more infrared to escape into space.

Water vapor strongly absorbs infrared of about 3 microns wavelength (3,000 nanometers), and so does carbon dioxide. Adding more carbon dioxide will not change the amount of energy passing out into space, since water vapor absorbs all of the energy near that wavelength. However, more carbon dioxide would make a difference at 4.5 microns wavelength (4,500 nanometers) because water vapor does not absorb at that wavelength. This means that doubling the amount of carbon dioxide in the atmosphere does not necessarily double the effect of carbon dioxide. In fact, most climate scientists believe that increasing carbon dioxide will increase the surface temperature, which will cause more water to evaporate. More water vapor in the atmosphere should further warm the earth's surface, but it will also cause more clouds that reflect sunlight back into space. More clouds will cool the earth. Under these competing processes it is believed that temperature will increase until a new equilibrium is reached.

■ U.S. federal laws concerning the environment

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Alaska National Interest Lands Conservation Act (1980)
Designated certain public lands in Alaska as units of the national park and national forest systems, the national wildlife refuge system, the National Wild and Scenic Rivers System, and the National Wilderness Preservation System. Provided comprehensive management guidance for all public lands in Alaska, including provisions regarding wilderness; subsistence; transportation and utility corridors; oil and gas leasing; mining; public access; hunting, trapping, and fishing; and implementation of the Alaska Native Claims Settlement Act (1971).

Antiquities Act (Act for the Preservation of American Antiquities; 1906)
Authorized permits for legitimate archaeological investigations and penalties for taking or destroying antiquities. Authorized presidents to protect all forms of American historical sites (natural, scientific, and archaeological) by proclaiming them to be national monuments.

Clean Air Act (1963)
Regulated air emissions from area, stationary, and mobile sources. Amendments in 1970 authorized the Environmental Protection Agency to create national air-quality standards to protect health and the environment, and required states to prepare and submit plans to implement clean air standards. Amendments in1977 extended the deadline for areas that had not reached compliance levels by 1975. Amendments in 1990 addressed such issues as acid rain, ozone depletion, and air toxins.

Clean Water Act (1977)
An amendment to the Federal Water Pollution Control Act of 1972; prohibited discharge of any pollutant from a source point into navigable waters of the United States unless a special permit had been obtained from the Environmental Protection Agency. Amendment in1987 (the Water Quality Act) included provisions for toxic pollutants, citizen suits, and funding of sewage treatment plants.

Coastal Zone Management Act (1972)
Provided for management of the nation's coastal resources, including the Great Lakes, and balanced economic developments with environmental conservation. Encouraged states and Native American tribal governments to preserve, protect, develop, and restore or enhance valuable national coastal resources. Amendments in 1990 called on states and tribes to develop and implement coastal nonpoint pollution control programs.

Emergency Planning and Community Right-to-Know Act (1986)
Provided assistance to local communities in protecting the environment and public health and safety from chemical hazards. Required each state to create a State Response Commission, to divide itself into districts, and to appoint an Emergency Planning Committee for each district. Required both commissions to provide the community with information on chemical hazards that might affect the public, and required the dissemination of procedures to be followed in the event of emergency hazardous situations.

Endangered Species Act (1973)
Repealed the Endangered Species Conservation Act (1969), which had amended the Endangered Species Preservation Act (1966). Implemented the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1973 and the 1940 Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere. Provided for the conservation of ecosystems on which threatened and endangered species of fish, wildlife, and plants depend and required the U.S. Fish and Wildlife Service to designate which plants and animals were threatened or endangered. Prohibited activities that could have adverse effects on endangered or threatened species and their habitats.

Energy Policy and Conservation Act (1975)
Enacted to help cut the amount of energy consumed by various industrial and consumer products. Introduced Corporate Average Fuel Economy (CAFE)

Major world national parks and protected areas

Narayanan M. Komerath and Padma P. Komerath

This article lists a selection of the world's most important protected areas and national parks, noting the year of establishment and approximate area of each. The list is organized alphabetically by continent and by country within continents. Many of the sites mentioned here are designated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as World Heritage Sites; more information on these protected areas is available at the official UNESCO Web site devoted to the World Heritage List: http://whc.unesco.org/en/list.

Many of the sites in the United States fall under the jurisdiction of the US National Park Service (NPS). A complete listing of that agency's managed areas can be found on its official website: https://www.nps.gov/findapark/advanced-search.htm.

Africa

Cameroon

Dja Faunal Reserve
Year established: 1950:
Area: 5,260 square kilometers (2,031 square miles)

Central African Republic

Manovo-Gounda St. Floris National Park (World Heritage Site)
Year established: 1988:
Area: 17,400 square kilometers (6,718 square miles)

Côte d'Ivoire

Comoé National Park (World Heritage Site)
Year established: 1983:
Area: 11,493 square kilometers (4,437 square miles)

Democratic Republic of the Congo

Garamba National Park
Year established: 1938:
Area: 4,920 square kilometers (1,900 square miles)

Kahuzi-Biéga National Park
Year established: 1970:
Area: 6,000 square kilometers (2,317 square miles)

Okapi Wildlife Reserve
Year established: 1992:
Area: 13,726 square kilometers (5,300 square miles)

Salonga National Park
Year established: 1970:
Area: 36,000 square kilometers (13,900 square miles)

Virunga National Park
Year established: 1925:
Area: 7,800 square kilometers (3,012 square miles)

Ethiopia

Simien National Park
Year established: 1969:
Area: 220 square kilometers (85 square miles)

Kenya

Lake Turkana National Parks (World Heritage Site)
Year established: 1997:
Area: 1,615 square kilometers (624 square miles)

Mount Kenya National Park/Natural Forest (World Heritage Site)
Year established: 1997:
Area: 1,420 square kilometers (548 square miles)

Madagascar

Rainforests of the Atsinanana (World Heritage Site)
Year established: 2007:
Area: 4,797 square kilometers (1,852 square miles)