Forests
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Forests are ecosystems dominated by trees; the technical definition specifies a tree-canopy cover of at least 10 percent. For millennia forests have provided food, medicinal plants, and wood to humans living in and near them; they have proved so valuable that humans have overexploited them. By the Middle Ages thousands of square kilometers of forests had been cut in Europe. At about the same time catastrophic deforestation took place in central Mexico that may have contributed to the collapse of the Maya civilization. In the *Critias*, written in the fourth century B.C.E., the ancient Greek philosopher Plato tells of the fifth-century deforestation of his native Attica and the attendant ecological damage, principally massive soil erosion. Deforestation has increased sharply during the twentieth and twenty-first centuries, threatening the very survival and evolutionary potential of many species, including human beings.

LOCATIONS AND BIODIVERSITY OF THE WORLD'S FORESTS

In 2007 the Food and Agriculture Organization of the United Nations (FAO) estimated worldwide forest cover at 39 million square kilometers, which is 30 percent of the earth's land area, with two-thirds of the forested lands distributed in only ten countries. If only intact forests (those not modified by humans) are counted, the estimated land area covered by forests is about 15 million square kilometers, or 10 percent of Earth's landmass (Greenpeace 2006). The three major forest biomes, described below, are tropical forests, temperate forests, and boreal forests.

**Tropical Forests**
Some 56 percent of the world's forests (21.8 million square kilometers) are tropical and subtropical. Tropical forests are found between the Tropic of Cancer (23.4° north latitude) and the Tropic of Capricorn (23.4° south latitude); subtropical forests are located between the tropics and 30° north or south latitude. There are two major types of tropical and subtropical forests: Deciduous forests grow where the climate is humid but has a pronounced dry season, and rain forests grow in areas with more than 2 meters of rain per year and no dry season. Tropical rain forests are found in Central and South America (especially Brazil), central and western Africa, eastern Madagascar, Southeast Asia, New Guinea, and northeastern Australia. In Central America, Madagascar, and the Philippines forests are located within the paths of tropical cyclones (also called hurricanes or typhoons), which can uproot or break trees. Trees in rain forests located within cyclone paths are shorter, on average, than trees in other rain forests. The Amazon rain forest, covering 5.5 million square kilometers, makes up more than half of Earth's remaining tropical rain forest. It is so large that its trees produce 20 percent of Earth's atmospheric oxygen and remove approximately 62 tons of carbon per square kilometer per year from the atmosphere.

Per unit area, tropical rain forests contain more species of plants, animals, and fungi than any other terrestrial biome. Two-thirds of Earth's plants and animals, including more than 175,000 vascular plant species (flowering plants, gymnosperms, and ferns) and more than 170 primate species (apes, monkeys, and lemurs) are found in tropical rain forests. Tropical rain forests are also home to approximately 50 million indigenous peoples.

**Temperate Forests**
Temperate forests once covered large expanses of western and central Europe, southern China, Japan, and eastern and western North America, approximately between 30° and 55° north latitude. Smaller areas of temperate forests are found in New Zealand, eastern Australia, southern Chile, Argentina, and South Africa. Today only 11 percent of the world's forests (4.3 million square kilometers) are temperate forests. Some 80 percent of the temperate forest biome is in the northern hemisphere, with the largest remaining forests in western North America. Although only 20 percent of temperate forests are in the Southern Hemisphere, they are ten times more species-rich per unit area than those in the Northern Hemisphere.

The world's largest and oldest organisms are found in temperate forests. Chile's west-coast Valdivian forest (the world's largest pristine temperate rain forest) contains 3,500-year-old *Nothofagus* (southern beech) and *Fitzroya* (Patagonian cypress) trees that average 60 meters in height and 5 meters in diameter. In California the coast redwood (*Sequoia*) can reach 110 meters in height and 8 meters in diameter, and the bristlecone pines, some of...
which are more than 4,800 years old, are the oldest organisms on Earth.

Depending on geography, climate, and soils, temperate forests are dominated by broadleaf deciduous “hardwood” trees (Europe and eastern United States), evergreen needle-leaf “softwood” conifers (western North America and New Zealand), or a mixture of both. Other temperate forests (China, southern Chile, South Africa, and eastern Australia) are dominated by broadleaf evergreen tree species. Fire is a major disturbance in temperate forests, especially those dominated by evergreen coniferous trees, with the fire interval (the time between two fires at a given location) ranging from a few decades to a century or more. Fires in coniferous forests can be “stand-replacement” disturbances that kill many of the adult trees and trigger the germination of a new cohort of seedlings. Indeed, many conifers (redwood and knobcone pines, for instance) require fire to regenerate, either because their seedlings cannot get started in the thick forest litter or because their cones will not open and release their seeds unless they burn, or both. Coniferous temperate forests are also prone to large-scale cyclical insect pest infestations that can kill entire stands, especially when trees are already stressed by drought or atmospheric pollution. Fire-suppression policies may also be responsible for pest outbreaks because natural fires keep insect pest populations low and break forest landscapes into mosaics of stands of different ages, keeping pest outbreaks spatially restricted.

**Boreal Forest, or Taiga**

Some 33 percent of the world's forests (12.9 million square kilometers) are boreal forests that grow in a nearly continuous belt of trees between 55° north latitude and the Arctic Circle, through Norway, Sweden, Russia (where the boreal forest is called taiga), Alaska, and Canada. This biome includes the coldest human settlements on the planet, with winter temperature falling below minus 65 degrees Celsius in parts of Siberia. The boreal forest is dominated by conifers such as larch, spruce, fir, and pine, but broadleaf trees such as birch, alder, willow, and aspen also abound. Trees have adaptations for survival in harsh winters, including tapered conical shapes that shed heavy snow loads. Wildlife includes large herds of caribou and predators such as wolves and bears. Migratory birds use numerous large lakes and wetlands in the summer. Several aboriginal communities live in the boreal forest, especially in Canada, where aboriginal First Nations make up 14 percent of the population.

**HUMAN IMPACTS ON FORESTS**

Humans have burned, cut, and otherwise affected forests for thousands of years. Only 4 percent of the world's forests are in Europe today because of a long history of forest removal dating back to the Greek and Roman empires, when the growth of cities and the building of military ships required larger and larger supplies of lumber and firewood. Although natural phenomena such as droughts may have also played a role, the decline of the Sumerian civilization (in what is now Iraq) around 2000 B.C.E. and of the Mayan Empire (in what is now southern Mexico) in the eighth and ninth centuries C.E. were due partly to uncontrolled forest exploitation, soil erosion, and the resulting increase in the salinity of arable lands that triggered large-scale food shortages and famines. Since the Industrial Revolution, however, the variety and scale of human impacts on forests has increased dramatically.

The industrial release of sulfur dioxide and nitrogen oxides from power plants creates acid rain, which has affected large forested areas in industrialized regions, especially eastern North America and Europe. Acid precipitation damages leaves, stressing trees and making them more vulnerable to diseases and fires or killing them outright. A third of Germany's forests, including the famous Black Forest, and more than 10 percent of Switzerland's forests have been affected. In the United States forests in New England and the Appalachian Mountains have been affected by acid rain, and rivers and lakes have also become more acid, killing fish and other aquatic wildlife and plants. Ozone, a pollutant generated by car exhaust in areas with sunny climates, can also damage tree leaves and affect forests.

Fire suppression, mostly in the temperate forests of western North America and Europe, has replaced natural fire regimes (fire frequency, season, and intensity) that played a critical role in fire-adapted forest ecosystems. Fire control has altered the succession of species in these forests, has suppressed the regeneration of fire-adapted tree species, and has allowed the accumulation of flammable litter, increasing the size and severity of fires when they burn out of control in dry and windy weather.

Global climate change has been linked to worldwide forest damage and forest biodiversity loss, and it may become the primary cause of forest loss. From Costa Rica, where “cloud forest” amphibian species are becoming extinct because of the rising altitude of clouds, to western Canada, where unusually large bark beetle outbreaks killed 130,000 square kilometers of pine forests in 2007, global climate change is having increasingly severe impacts on Earth's forests.
Dead trees further contribute to global climate change by releasing into the atmosphere carbon previously fixed in wood and soils.

The major human impact on the world's forests, however, comes from deforestation. The FAO estimates that the global rate of deforestation is about 130,000 square kilometers (the size of Louisiana) per year, which means that from 1990 to 2005, the world lost 3 percent of its forests. The main causes of deforestation include tree harvesting for wood or paper pulp, clearing for agriculture or livestock production, urban development, and tree harvesting for firewood. From 2000 to 2005, the yearly deforestation rate in the Amazon forest alone was 22,400 square kilometers (the size of New Jersey); making room for livestock pastures or soybean production accounted for 90 percent of this activity. Tropical deforestation has caused the extinction of many animal species and threatens others, including the mountain gorilla of central and east Africa and the Sumatran tiger.

Temperate and boreal forests are also being cut at an alarming rate. Nearly 9,000 square kilometers of Canada's boreal forest are logged every year for paper and timber, destroying habitats for caribou, grizzly bears, wolverines, and other wildlife, thereby threatening these species with extinction. In the Southern Hemisphere thousands of square kilometers of Chile's forests have been logged to make wood chips for export; these areas have been replaced with plantations of exotic species such as Monterey pine (more than 10,000 square kilometers have been planted) that cannot support the rich animal and plant biodiversity found in the native forests. Half of the coastal Valdivian forests of Chile have been cleared, and in the U.S. Pacific Northwest only 15 percent of the original forests remain.

FOREST CONSERVATION

People on all continents have practiced some form of forest conservation for several millennia. Protection laws regulated the use of forests in ancient Persia as early as 1700 B.C.E., and Celtic tribes in Europe had set aside sacred forests by about 500 B.C.E. Scholars have documented rules against overharvesting of trees among some North American Indian tribes and the designation of sacred forest groves with tree-cutting taboos—some still in force—in and around burial sites in Africa and Madagascar. Around 250 B.C.E. in India the earliest written laws sanctioning the conservation of forests and the regulation of hunting were promulgated under the Maurya dynasty. Throughout the tropics agroforestry (the cultivation of crops and trees together) has been practiced for hundreds of years, preserving many native tree species from extinction.

The tension between the modern European and North American conservation movement and the rights of indigenous people was foreshadowed in the writings of the American naturalist and preservationist John Muir (1838–1914), who, upon encountering a group of Mono Indians on the trail, reflected, “Somehow they seemed to have no right place in the landscape, and I was glad to see them fading out of sight down the pass” (1992, p. 343). The conservation policies of the U.S. government focused on landscapes, and the legislation that created national parks in the nineteenth century did not recognize traditional indigenous hunting-and-gathering rights in those areas.

Many parks protecting forest ecosystems were created in the late 1800s and early 1900s in the United States, Australia, Canada, Sweden, and South Africa, where Kruger National Park was established in 1926. In contrast to the United States and Canada, where national parks were carved out of largely pristine landscapes, national parks in Europe often incorporated human-modified landscapes such as farms, managed forests, and even villages. Nonetheless, the American national park system has become the most widespread model of forest conservation throughout the world. From 1962 to 2003, the number of “protected areas” worldwide increased from about 1,000 to more than 100,000, mostly in terrestrial ecosystems, including nearly 8 million square kilometers of forests, of which more than 4.5 million kilometers are in tropical forests (approximately 20 percent of the tropical-forest biome) and more than 3 million are in temperate forests (approximately 12 percent of the temperate-forest biome).

In developing countries, where populations are mostly rural and depend on land and natural resources for survival, the effectiveness and equity of the national park model, with its emphasis on removal of human land-based subsistence, has been the subject of much research and debate. The intensity of that debate sprang, in part, from the radicalization of a section of the environmental movement in the 1960s. Arguments for valuing forests intrinsically (the ecocentric viewpoint) rather than for their value to humans (the anthropocentric viewpoint) were articulated by proponents of Deep Ecology, who sometimes advocated the use of monkeywrenching or ecotage, the sabotage of human activities perceived as threatening natural ecosystems. Some monkeywrenching methods used in the 1980s included driving metal spikes into trees of U.S. Pacific Northwest old-growth (pristine) forests to prevent logging. Internationally, the Deep Ecology view that humans should be removed from ecosystems targeted for
conservation influenced the methods used to establish parks and forest reserves. In Africa especially, there were expropriations of indigenous peoples from newly created parklands. In Tanzania the establishment in 1960 of Arusha National Park involved the forcible removal of Meru villagers and Maasai herders, and in the Democratic Republic of the Congo the establishment in 1970 of Kahuzi-Biéga National Park resulted in the displacement of more than 13,000 Twa, Shi, Tembo, and Rega inhabitants.

THE HUMAN CONTEXT OF FOREST CONSERVATION

There is widespread agreement about the worthiness of the goal of conserving the world's forests and their plant and animal biodiversity, but there is also widespread disagreement about the best means to this end. Steven Brechin and his coauthors (2003) suggest that too many conservation programs focus on conservation objectives (the “what”) and not on the social and political processes that can help realize those objectives (the “how”). In several instances, they argue, expediency has rationalized conservation without due consideration for indigenous rights. Neither the Meru of Tanzania, the Twa of the Democratic Republic of the Congo, nor the Chimane of Bolivia were consulted before being expelled from the forests that had supported their traditional livelihood. In all cases these communities ended up poorer and more marginalized.

Conservation biologists such as Thomas Struhsaker (1998) or John Terborgh et al. (2002) argue that incorporating economic development for, or sustainable resource use by, local communities (a “conservation through development” model) cannot substitute for totally protecting forests and will eventually drive ecosystems in protected areas to extinction. They suggest that even though indigenous people have lived at sustainable levels within their forest environments in the past, there is no guarantee that they will continue to do so, given global pressures for modernization and integration into the modern economy.

Paul Wolvekamp (1999) counters that many indigenous cultures are, in fact, responsible for the pristine condition of many forests. The Kayapó indigenous people of Brazil, for instance, have protected the boundary and integrity of the 110,000 square kilometers of the Kayapó Reserve forest against the encroachments of logging and mining. Wolvekamp argues, therefore, that it is counterproductive for western-based conservation organizations to advocate the removal of indigenous groups from protected areas or to urge the cessation of their traditional use of the forests. He suggests such proposals lack legitimacy because the carbon footprint of large-scale tourism in parks—considering the air travel involved—is more deleterious than the global impact of indigenous communities living inside these parks.

James Fairhead and Melissa Leach (1996) document the damaging consequences of the dogma that indigenous people can only mismanage their forests; they report that this outlook led to a misreading of the forest-savanna transition of Guinea, in western Africa, as the product of human-caused deforestation. Fairhead and Leach show, rather, that farmers had a long tradition of creating and maintaining forests around their villages. Nancy Peluso (1992) found that the many instances of deforestation she studied in Java resulted from inappropriate top-down state control of forests previously managed appropriately by peasants. She and Roderick Neumann (1998) have also challenged the often-assumed correlation between indigenous population growth and increased deforestation, arguing that it is untested and often at odds with local realities.

Janis Alcorn (1993) and Steven Brechin and his coauthors (2003) have suggested that indigenous expropriations, especially when enforced militarily, have undermined the perceived legitimacy—and therefore the effectiveness—of forest conservation programs. Michael Soulé (1991) agrees with Alcorn that many park-style conservation projects have failed and have undermined the ability of indigenous communities to protect forests. Because nature conservation is essentially a mechanism of resource control, Brechin proposes that forest conservation strategies must be both ecologically sound and socially just to gain legitimacy in the eyes of all stakeholders. To succeed in the long term, Alcorn argues, such programs must involve local communities and indigenous people. Brechin sees nature conservation as a complex social enterprise that requires negotiated compromises, not one-sided, state-imposed, short-term solutions; he contends that the social cost of global forest conservation should not be borne solely by the indigenous forest communities.

NEW DIRECTIONS IN FOREST CONSERVATION

Soulé argues that nature conservation should be adapted and tailored to various geographical and political contexts.
Accordingly, it is worth reviewing a small sample of forest conservation efforts in which local communities have been an integral part of the solution.

**Tropical Forests**

In Madagascar partnerships among the Department of Water and Forests, the University of Antananarivo, nongovernmental organizations (NGOs) such as the Worldwide Fund for Nature, and local communities have made successful use of the *Dina*—a traditional system of rules and regulations governing rights of usage, timing, quantity, and frequency of harvest—to guide resource use by villagers. Such contracts have been implemented in the Manambolo Valley (a biodiversity corridor linking the Andringitra and Ranomafana National Parks) and in the Tampolo littoral forest, protecting rain forests and their unique plants and animals, including several species of lemurs. In eighteen other tropical countries, the NGO Rainforest Foundation adopted a rights-based, social-justice forestry strategy to halt rain forest loss by helping forest-dwelling communities establish land tenure rights and greater control over the use of forest resources.

To promote social equity in bioprospecting (the search for medically promising plant compounds for commercial use), the National Biodiversity Institute (INBio) of Costa Rica, an NGO, was established in 1989. INBio helps rural communities become active participants and beneficiaries, based on the assumption that the sustainable use of natural forest compounds can benefit local communities economically and reduce the financial pressures that can drive some forest communities to cut trees for cash. Similarly, “extractive reserves,” pioneered by Mary Helena Allegretti and Chico Mendes (murdered in 1988 for his opposition to deforestation of the Brazilian Amazon for cattle ranching), are forest reserves where local residents are allowed to tap trees for rubber, gather fruits and nuts, hunt wildlife, and harvest wood within sustainable limits, providing forest-generated income to local communities and diminishing incentives to deforestation.

As long as soils are not seriously compacted by heavy equipment or damaged by erosion, tropical forests can recover from logging or agriculture. Carl Sauer (1958) suggested that many tropical forests once classified as pristine had in fact been widely manipulated and transformed by South American Indian communities with fire and plantations of useful tree species. Recent findings that large sections of the Amazonian rain forest are in fact secondary forests (forests that grow back following a disturbance) have supported Sauer's hypothesis. Robin Chazdon (1998) therefore suggests that today's tropical forest conservation agenda should be visionary and not focus exclusively on protecting “pristine” forests; disturbed forests and secondary forests that have a good potential for recovery could also be protected, to become the “pristine” forests of tomorrow.

**Temperate Forests**

In 1992, in cooperation with the Environmental Defense Fund, the Wasco, Warm Springs, and Paiute tribes of Oregon developed a management plan for the Warm Springs Reservation, 60 percent of which is forested. The tribes, which earn a large part of their income from timber sales, voluntarily reduced the timber harvest by half and established best-management practices for future timber sales. The plan sets new guidelines for managing protected forests, fisheries, and other nonforest resources.

**Boreal Forests**

The Boreal Forest Conservation Framework (BFCF) is an NGO that acts as a liaison between Canadian conservation organizations, industry groups, First Nations, and local governments in support of research and forest conservation. The BFCF seeks to protect more than half of Canada's boreal forest in a network of large, interconnected forest areas while maintaining long-term economic benefits for communities and respecting the land rights of aboriginal groups. Thousands of miles away, in the taiga of the Russian Far East, the Udege aboriginal group spearheaded the creation of the Russian Far Eastern Association for the Use of Non-Timber Forest Products. The group's main goal is to link village organizations, traders, processing plants, and scientific institutes to develop nontimber-based indigenous economies and reduce logging, thus preserving the forest habitats for endangered species such as the Amur tiger, cranes, and salmon.

**CONCLUSION**

Conserving the world's forests is an enormous social enterprise with an urgent ecological goal. Losing the world's forests would be an ecological catastrophe. Averting that disaster while preserving the rights and dignity of
indigenous peoples remains the unfulfilled challenge to the scholars, activists, NGOs, and governments that know that the health of Earth's ecosphere—indeed, perhaps the very survival of life on the planet—hinges on the health of the world's forests.

**BIBLIOGRAPHY**


*Robin Chazdon and John Silander Jr. provided valuable comments on the draft version of this article.*