Chapter 7

The Forestry Sector

Photo credit: American Forestry Association

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OVERVIEW AND SUMMARY

Humans have long altered forests and, in the process, affected the flow of greenhouse gases—particularly carbon dioxide ($C0_2$)--between forest lands and the atmosphere. In recent decades, the net flow to the atmosphere appears to have accelerated. Opportunities exist to moderate this trend through practices such as increasing forest productivity and tree planting in the United States, and agroforestry, better timber harvest management, use of nontimber forest products, and reforestation in the tropics. Most of these also will provide other benefits such as protection of watersheds, riparian habitats, and biodiversity; provision of food; reduced soil erosion; and stability in nutrient and hydrologic cycles.

Most current forest-related emissions come from tropical forests. These forests, located almost exclusively in developing countries, are being deforested and degraded on a widespread, unprecedented scale.[1] Estimates indicate that tropical deforestation accounts for 7 to as much as 31 percent of worldwide CO_2 emissions from all sources (see figure 7-l). Temperate-zone deforestation, mostly in industrialized countries, contributes comparatively little CO_2 emissions; however, temperate-zone forests underwent massive alterations in the past.[2]

Since industrialized countries contribute the vast majority of global CO_2 emissions through their use of fossil fuels (see figure 7-l), halting tropical deforestation will not stop the accumulation of greenhouse gases in the atmosphere. Nor is reforestation feasible on a large enough scale to totally offset CO_2 emissions from fossil fuel use.[3] To reduce greenhouse gas emissions, industrialized countries must first reduce fossil fuel use in their building, energy, manufacturing, and transportation sectors (see chs. 3 through 6).

At the same time, temperate-zone forestry management practices might offset---+ver the short term-some emissions from industrialized countries. Although difficult, this can be achieved by:

- increasing carbon storage in existing forests;
- growing tree crops on unforested land for use as fuel; and
- planting and maintaining trees in urban areas and marginal crop and pasturelands.

OTA estimates that forestry-related practices in the United States might be able to offset about 2 percent of U.S. 1987 carbon emissions from fossil fuel combustion in the year 2000 and 7.5 percent in 2015 (see figure 7-2), at an annualized cost in 2015 of $10 to $13 billion per year (see app. A for cost estimates). Congress could promote such practices by enhancing or augmenting existing forest management and tree planting programs of the U.S. Forest Service and the Agricultural Stabilization and Conservation Service, and by enhancing the biomass energy research program of the Department of Energy. Congress also could consider using financial incentives (e.g., tax policies to make investments in forest management more attractive; tax on fossil fuels to make biomass fuels more competitive).

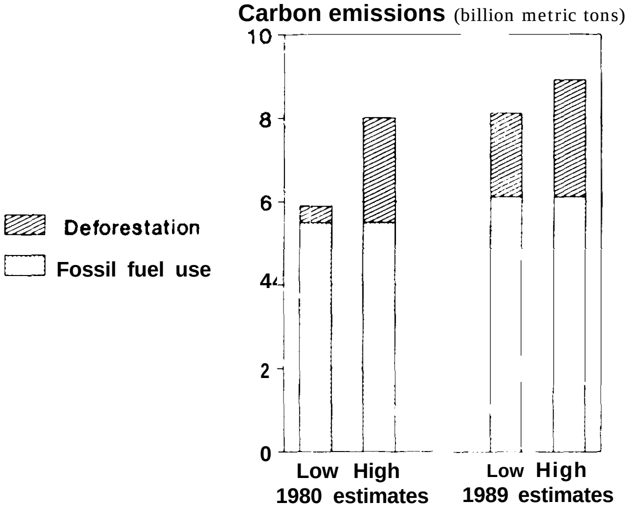
There are several caveats to this potential for offsetting emissions. Trees planted today can continue to store carbon beyond this report's 25-year timeframe. But this carbon eventually will be released to the atmosphere, either when trees die and decompose naturally, when they are harvested and burned, or when products made from wood eventually decompose. But unless the wood is used to displace fossil fuel or is permanently stored under conditions that will not allow decomposition, the carbon offsets in later years will dwindle. In addition, current estimates of forestry-related offsets assume that increasing the carbon storage rate in a

1 'Deforestation" means converting forest land to other vegetation or uses (e.g., pasture, cropland, dams). "Degradation" involves practices which leave trees as the predominant vegetation but which degrade overall forest quality (e.g., soil erosion, damages to trees and streams from selective logging).

2 In this report, the term ''temperate-zone forests' refers to temperate and boreal coniferous forests and temperate deciduous forests.

3 For example, estimates of how much tree planting would be needed to offset global CO_2 emissions range from 500 to almost 1 billion hectares of new plantations exhibiting moderately high growth rates (1.55, 239, 240). The lower end of this range represents over 1.5 times the total area of U.S. forest and more than 15 percent of the world's total closed forest area,

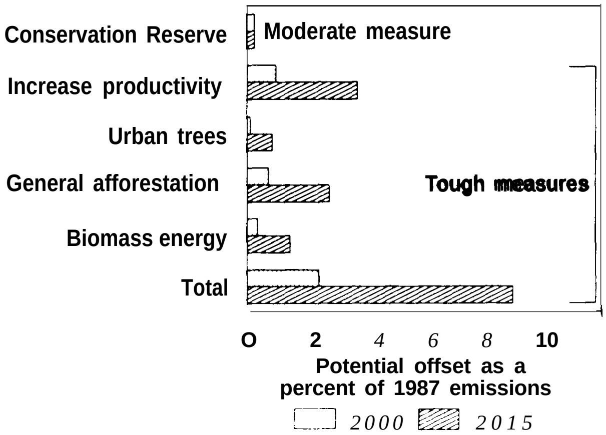
Figure 7-1 —Estimates of Relative Carbon Emissions From Fossil Fuel Use arid Tropical Deforestation, 1980 and 1989



"Low" and "High" represent the range of estimates for carbon emissions during that year.

SOURCES: *1980 deforestation estimates* from R.K. Detwiler and C.A.S. Hall, "Tropical Forests and the Global Carbon Cycle," *Science* 239:42-47, Jan 1, 1988; and from R.A. Houghton et al., "The Flux of Carbon From Terrestrial Ecosystems to the Atmosphere in 1980 Due to Changes in Land Use: Geographic Distribution of the Global Flux," *Tellus* 39B:122-139, 1987. *1989 deforestation esthetes* from R.A. Houghton, "Emissions of Greenhouse Gases," Part 4 (pp. 53-62) in N. Myers, *Deforestation Rates in Tropical Forests and Their Climatic Implications* (London: Friends of the Earth Ltd., 1989); and from N. Myers, *Deforestation Rates in Tropical Forests and The/r Climatic Implications* (London: Friends of the Earth Ltd., 1989). *1980 and 1989 fossil fuel use* from U.S. Department of Energy, *International Energy* Annual, DOE/EIA-0219(88) (Washington, DC: Energy Information Administration, November 1989) (using estimated 1988 emissions, the latest year for which estimates are available, as a surrogate for 1989 emissions).

Figure 7-2—Potential for Forestry Practices To Offset U.S. Carbon Emissions, Relative to 1987 Emissions Levels



For comparison with the energy model (see app A), OTA considers the Conservation Reserve Program to be a "moderate" measure, primarily because it is already being implemented. The other forestry measures are considered "tough" measures because they will require greater efforts and investments to be fully achieved. These estimates all depend on assumptions discussed in the text.

SOURCE: Office of Technology Assessment (from table 7-1).

forest's commercial timber component will also increase the total storage rate in the entire forest ecosystem. Finally, forests-and the feasibility of using forestry practices to offset emissions-are likely to be affected by future climate changes. Therefore, forestry options in industrialized countries cannot be considered a substitute for reducing total energy use or developing non-fossil fuel alternatives, but rather as a way of "buying" time while developing alternative sources and improving the efficiency of their energy use in general.

To reduce their current CO_2 emissions, developing countries need to stop tropical deforestation and degradation, which occur as forests are converted to temporary agriculture (''shifting" cultivation) and permanent agriculture (including cattle ranching) and as a result of poor timber harvesting practices.

However, these activities are driven by underlying social, economic, and political factors—poverty and lack of land tenure for most people, national development policies, and foreign debts—that are exacerbated by rapid population growth (337). Emissions from fossil fuel use are relatively less important now but are likely to increase significantly as these countries develop (ch. 9).

The primary needs in developing countries, then, are to remove incentives for deforestation; provide for population planning, land reform, and debt reduction; and provide alternative livelihoods for millions of shifting cultivators and thousands of rural communities. The suitability of alternatives such as agroforestry and ''sustainable' agriculture, improved forest management, increased use of nontimber forest products, and reforestation depends on site-specific conditions and, in most cases, giving local people a vested interest in seeing them implemented.

The United States can ensure that its foreign aid assistance programs (primarily of the U.S. Agency for International Development), and those of multilateral lending and international assistance organizations (e.g., World Bank, U.N. Food and Agriculture Organization), address developing country social

Box 7-A—What Happens to Carbon in a Forest?

During the day, plants take carbon dioxide (CO_2) from the atmosphere and convert it into organic compounds such as carbohydrates by using solar energy and water (i.e., photosynthesis). Plants emit CO_2 during respiration, when they use the energy stored in these compounds. The balance favors the net accumulation of carbon in trees, shrubs, herbs, and roots. Much of the carbon in forests, however, is "hidden' '-almost 60 percent on average in U.S. forests is stored below ground in organic matter (including roots) and organisms in the soil (18, 19).

The rate of carbon storage in an ***ecosystem*** is known as "net growth' or "net productivity. " Young, vigorous forest stands tend to exhibit the greatest net growth rates. The total carbon stored at any time is greatest in older, mature forests, even though they have a net growth rate near or sometimes less than zero (156, 288).

Unmanaged forests normally change over time as individual trees die and as new species move in during succession (178). When trees die and decompose, they emit CO_2 (although generally over a longer period and at a slower rate than if harvested). The rate at which changes occur is determined by factors such as competition with other plants for light, nutrients, and water, as well as by pest outbreaks and fire.

When forests are cut, the effect on atmospheric CO_2 depends on how much carbon was stored (i.e., total biomass), what happens to the cut wood, and how the lands are managed. If the time scale is long enough and the land is used for a series of harvests, then the flux of carbon can be cyclic.

When cut wood is left on a site, microorganisms (e.g., fungi, bacteria) "decompose" it, along with leaf and branch litter. Through their metabolic activities, microorganisms convert carbon in the wood into CO_2 and other compounds such as methane that are emitted to the atmosphere. Decomposition rates depend on factors such as oxygen availability, temperature, and moisture.

If wood is burned, CO_2, methane, nitrous oxide, particulate matter, and other chemicals are emitted. In some cases, though, using wood as a fuel can replace the use of fossil fuels; over one-half of the wood removed from U.S. forests in the early 1980s was burned for energy, either by the forest products industry or in households (274). The net effect on CO_2 depends on combustion efficiency, whether fossil fuel use is actually replaced, and the rate of carbon storage in vegetation that replaces the harvested wood.

When wood is converted into products, some carbon is stored until the products begin to decompose. Relatively durable products such as construction lumber can retain carbon for decades or centuries; about one-fourth of U.S. stemwood harvested during the last 35 years has been converted to such products (241). Relatively short-lived products such as paper may decompose and release CO_2 or methane after being discarded, depending on conditions at the discard site; recent research, though, indicates that decomposition of organic materials in landfills proceeds slowly (209, 281, 327).

After harvesting, CO_2 is again taken in by new vegetation growing on the site, assuming the land is not converted to a highway, reservoir, or other nonvegetative state. The net effect in offsetting CO_2 emissions from the harvesting depends on the type of vegetation (e.g., crops, pasture, or trees), the rate at which it stores carbon, the rate at which carbon reaccumulates in the soil, availability of nutrients, and how long the vegetation grows before being harvested again.

and economic needs and promote alternative land-use practices. The United States also could work to make the Tropical Forestry Action Plan and the international Tropical Timber Organization more effective vehicles for promoting forest conservation and improved commercial forest management. In addition, the United States could support a global forestry conservation protocol, as recommended by the intergovernmental Panel on Climate Change (1 14, 1 14a).

SETTING THE STAGE: FOREST AREA AND EMISSIONS

Carbon is stored in forests as they grow and is released when vegetation is removed or disturbed (see box 7-A). The net global flux of carbon from forests to the atmosphere has not been measured directly, but it has been estimated using data on changes in forest cover and on the amount of carbon held in vegetation and soils (105).[4]

[4]Other gases besides CO_2 are emitted when forests are cleared or **burned.** Fires, for example, release methane, carbon monoxide, nitric and nitrous oxide, methyl chloride, and other compounds, as well as particulate matter (7, 8, 44a, 48, 124, 126, 137, 145, 206, 219).

Temperate-Zone Forests

Temperate-zone forests (i.e., boreal and temperate conifer forests, and temperate deciduous forests) cover about 2.2 billion hectares, or 8.5 million square miles (338). They are the source of most wood and paper products used by industrialized nations. About 42 percent are in the U. S. S. R., 20 percent in Canada, and 14 percent in the United States.

Changes in Forest Cover

Current changes in temperate-zone forest cover are small. Large-scale deforestation occurred mostly in the past (e.g., 50 to 200 years ago in North America and up to 5,000 years ago in the Far East). During this century, forest cover has increased in many areas of North America and Europe (9, 288) through natural regeneration and planting of trees in areas that have lacked forests for centuries, although it has decreased recently in the United States.

Nevertheless, changes do occur. For example, wooded areas near many U.S. cities are undergoing rapid conversion for real estate development, which often exacerbates runoff into nearby freshwater and marine habitats (277). The U.S. Forest Service (299) estimated that U.S. forest land declined by almost 6.6 percent (21 million hectares) from 1953 to 1987 and will decline another 2.2 percent (7 million hectares) by 2010, mainly through conversion to reservoirs, urban developments, highways, airports, and surface mines. Losses in forest cover and composition also are possible from airborne pollutants (80, 178, 276, 280).

Carbon Emissions

The magnitude of carbon reservoirs and emissions in the Northern Hemisphere are Uncertain.[5] Published estimates suggest that CO_2 emissions from temperate-zone deforestation are relatively low, around 25 to 130 million metric tons per year; emissions are thought to be greatest from China and the U. S. S.R., less significant from the United States and Canada (103, 107, 161).

Extensive burning (from natural and human causes) of forests and other biomass occurs in temperate latitudes, but the magnitude of associated emissions is Uncertain.[6] While the amount burned in both the United States and Canada generally declined from the 1920s through the 1970s, this trend reversed during the 1980s and increased to a post-war high.[7] Large fires also affected other temperate areas, including over 1 million hectares of boreal forest in China and over 4 million hectares in the U.S.S.R. in 1987 (34, 81, 138, 229, 256). Fires also affect albedo (the Earth's reflectivity) and thus can have feedback effects on local climate. Crutzen and Andreae (44a) estimated that biomass burning in the temperate and boreal zone releases 150 to 300 million metric tons C yearly.

Tropical Forests

Changes in Forest Cover

Tropical forests cover about 2.1 billion hectares.[8] Almost all are located in developing countries, where they make up two-thirds of woody vegetation.[9] They are home to some of the last hunter-gatherer tribes, harbor at least half of the world's organisms, and are the source of many products (e.g., wood, medicines, fibers, fruits, nuts) (275).

[5] For example, one analysis *(23, 24) concluded* that previous estimates of carbon content in boreal forests are too high. Another (257), though, suggests that the Northern Hemisphere may be a larger terrestrial carbon sink than previously thought; whether this would involve boreal forests or other ecosystems such as tundra is unknown.

[6] Other catastrophic incidents also affect forests. In 1989, for example, Hurricane Hugo darnaged at least 1 million hectares of forest in North and south Carolina (33, 199).

[7] In the United States, over 1 million hectares burned *yearly* from 1985 to 1989, including over 2 million hectares in 1988 (205). However, fires consumed over 10 million hectares annually during 16 years from 1926 to 1943 (287, 297). In Canada, over 24 million hectares burned during the 1980s, including over 6 million in 1989, more than repotted in any other decade (55, 56, 189, 313). These estimates, however, also include some fires on nonforest lands (e.g., grasslands, marshlands).

[8] They occur in many forms, under moisture conditions that range from wet (Amazonian ''rain' forest) to seasonally moist (Asian monsoon forest) to dry (Sahelian open savanna).

[9] The United States has jurisdiction over about 0.5 percent of tropical forests, mostly in Puerto Rico, the Virgin Islands, Hawaii, American Samoa, and Micronesia (275, 278). Other developed countries, such as France, also have small areas of tropical forest under their jurisdiction.

Photo credit NASA/Courtesy Earth Resources Laboratory, John C. Stennis Space Center, Mississippi

This Landsat image shows an area in southern Mexico where a large rural population has converted most tropical forest there into agricultural fields. In the adjacent area in Guatemala, the rural population is sparse and the forest is still mostly intact.

Deforestation of tropical forests (including fa.l-10W) is occurring at an unprecedented rate.[10] Aside from carbon emissions, other effects of deforestation and degradation-soil erosion, increased down-stream flooding, desertification, decreased bio-diversity, and effects on local microclimates-are enormous.

The overall rate of deforestation appears to have increased in the last decade. As of 1980, the Food and Agriculture Organization (FAO) estimated that 11.3 million hectares of closed and open forests were being cleared annually (70).[11] For 1989, however, a preliminary report from FAO's 1990 Forest Resources Assessment estimates that defor-estation rates have increased by over 50 percent, to around 17.1 million hectares (or 1.2 percent of tropical forests) per year (76, 77, 264).[12]

Carbon Emissions

The level of carbon emissions from tropical deforestation is uncertain. Estimates for 1980 range from 0.4 to 2.5 billion metric tons C per year (50,51, 103, 105, 106, 107, 108). Since these estimates do not include degradation of forests, and deforestation rates appear to be greater now, current emissions might be higher, Indeed, Houghton (104, 105) estimated that emissions in 1989 were between 2.0 and 2.8 billion metric tons, roughly 25 to 31 percent of all carbon emissions (see figure 7-1).13

MANAGEMENT PRACTICES IN U.S. FORESTS

Forestry-related management practices can store carbon and/or offset some CO_2 emissions in temperate-zone areas. For the United States, OTA estimates that by 2015 a combination of practices might offset approximately 7.5 percent of current (i.e., 1987) U.S. CO_2 emissions from fossil fuel use (see table 7-l). Some observers contend that higher rates are possible for individual practices (e.g., 230, 343). Regardless, the practices also could provide other benefits, many of which are goals of existing U.S. legislation-e. g., reduced soil erosion, improved water quality, and increased biodiversity, aesthetic qualities, and recreational opportunities.

[10] The term "fallow" or "secondary" refers to forests cleared for agriculture but now in the process of regenerating.

[11] While this estimate has been debated or modified by others (25, 27, 50, 51, 70, 75, 107, 108, 155, 162, 172, 174, 288), it is based on the largest and most systematic database available. No estimates exist regarding overall rates of forest degradation, but it is important in many areas, for example in South and Southeast Asia (26).

[12] The annual rate of deforestation as of 1989 was an estimated 1.7 percent in Africa, 1.4 percent in Asia, and 0.9 percent in Latin America (where over 60 percent of global deforestation was occurring). Myers (174) estimated that deforestation in 1989 was 90 percent higher than a decade earlier, although this has not been confirmed (114).

[13] These estimates do not necessarily account for the fact that disturbed or degraded soils and vegetation can still slowly sequester carbon over time (28, 15 G), nor that deforested lands also typically support vegetation (e.g., grassland, annual crops).

Table 7-1—U.S. Forest Management: Potential Carbon Storage/Savings and Percent Offset of 1987 Carbon Emissions From U.S. Fossil Fuel Use, for 2000 and 2015

Management practice	Assumptions [a]	Million metric tons C in 2000[b]	Percent of 1987 carbon offset in 2000[c]	Million metric tons C in 2015b	Percent of 1987 carbon offset in 2015C	Examples of other benefits
Moderate measures?						
Conservation Reserve Program (CRP)	Total enrollment 2.3 million ha 1995, growth rate of 1 metric ton C/ha	2.3	0.2%	2.3	0.2%	Soil and watershed protection
Tough measures!						
Increase productivity	Programs begin 1995. Nonindustry: 37 million ha, additional storage 0.5 metric tons C/ha/yr. Timber industry: 20 million ha, storage increment 1 metric ton C/ha/yr.	10	0.80/0	40	3.10/o	Increased timber revenues
General afforestation (excluding CRP)	Programs begin 1995. Total 30 million ha, storage increment 1 metric ton C/ha/yr	7.5	0.6%	30	2.30/o	Biodiversity, soil, and watershed protection
Biomass energy crops	Program begins 1995. 0.5 million ha planted/year, storage increment 3 metric tons C/ha/yr	4	0.3%	15	1.2%	Less dependence on other energy sources
Urban trees	Program begins 1995.100 million trees/yr, no savings from shading until 2005	1	0.1%	9	0.7%	Less heat island effect, aesthetics
Total			2.0%		7.5%	

[a]See text for greater detail; in general, assumptions do not directly reflect economic feasibility.
[b]Accounting for gradual implementation over a 25-year period; i.e., some planting and growth or other management occurs in year 1, but some does not occur until year 25. ‘
[c]Percent of estimated 1.3 billion metric tons C from fossil fuel use. Individual percentage offsets not additive.
[d]For comparison with the energy model (see app. A), OTA considers the Conservation Reserve Program to be a "moderate" measure, primarily because it is already being implemented. The other, "tough" measures will require greater efforts and investments to be fully achieved.

SOURCE: Office of Technology Assessment, 1991.

Photo credit: Forest Service/USDA photo

Douglas-fir is the most abundant and important commercial timber tree in the West. It is found in the Rocky Mountains (as shown here on a steep slope in Colorado), Pacific Northwest, and Pacific Southwest. Douglas-fir forests on the Pacific slope in the Northwest are among the most productive softwood forests in the United States.

Managing Existing Forest Land and Products

Increasing Productivity

In principle, forests can be managed to increase the rate at which they store carbon (i.e., increase productivity). Most people are concerned with increasing the productivity of the ''industrial' portion (i.e., excluding branches, leaves, litter, etc.) of commercially available timber, because investments in such management offer a chance for increased economic returns (as opposed to trying to increase productivity in wilderness areas and parks). Whether increasing the rate of carbon storage in commercial timber means that the rate of total carbon storage in the entire forest ecosystem also increases, however, is a critical, generally untested, assumption. The discussion here assumes that total carbon storage also increases, but this requires testing.

''Conventional' management often is used to enhance productivity of commercial species. For example, ''thinning' involves removing some young trees or temporarily suppressing other vegetation to lessen competition (for water, light, and nutrients) and to adjust the number of trees per hectare. "Stocking' refers to obtaining the desired number of trees, by thinning or additional planting, Growth rates for the commercial portion of existing U.S. forests are estimated to be 60 percent on average of their fully stocked potential (155).

More ''intensive management might increase growth rates for the commercial portion beyond this potential, at least for short periods (60, 156, 239, 274). This includes site preparation (e.g., minor drainage, fertilization), genetic selection of superior strains, improved nursery practices, and protection from fire, insects, and disease. In one study, drainage, fertilization, and genetic selection resulted in two- to four-fold increases in Douglas fir and loblolly pine growth rates (60). Similar results have been obtained with sycamore, eucalyptus, and other pines (156, 177).

Intensive management is generally more suitable for newly planted forests than for existing forests. Its long-term feasibility is uncertain, however, partly because research on this practice only began intensifying in the late 1970s. High growth rates have been attained only for young individuals of selected species and have not yet been sustained over extended periods (155); again, whether total productivity of affected areas increases is unclear. Increased use of fertilizers and herbicides could have other environmental effects (e.g., N_2O emissions and groundwater contamination from fertilizer application, CO_2 emissions from fertilizer manufacturing), and preferences for monoculture would reduce biological diversity.[14] Research is needed on how repeated harvesting of intensively managed forests would affect soil structure and erosion, wood y debris, nutrient availability, and below-ground carbon storage (over one-half on average of the carbon

[14] One study in red pine and oak/maple forests in Massachusetts concluded that fertilization also reduced methane consumption by soil microorganisms by about one-third compared to control plots (255) (bacteria in forest soils produce and consume methane; methane-producing bacteria live in deeper and wetter portions of soil where oxygen is absent, while methane-eonsuming bacteria live in surface layers of soil where oxygen is present). How this might affect atmospheric concentrations of methane is unknown, The potential significance of this effect deserves more research.

Box 7-B—Productivity and Ownership of U.S. Forests

U.S. forests cover about 295 million hectares, or 32 percent of total land area, roughly one-quarter less than in colonial times (155,299). Overall forest area declined by about 6.6 percent (or 21 million hectares) between 1953 and 1987. However, commercial timber **volume** has **increased, at** least **during the last two decades. From 1970 to 1987,** overall area declined by 3.5 percent but commercial volume increased by an estimated 4 percent (299, 300). Forest area is expected to decline by an additional 2.2 percent from 1987 to 2010 (about 0.3 million hectares per year), due to construction of reservoirs, highways, and airports; urban development; surface mining; and other activities (300).

Timberland Ownership--Two-thirds of all U.S. forests are considered timberland--i.e., producing or capable of producing industrial wood (which does not include roots, bark, branches, and leaves) at a rate of 20 cubic feet or more per acre (or 1.4 cubic meters per hectare) per year (300). Some timberland is in parks and wilderness areas and thus is protected from harvest (14 million hectares), but most is commercially available (1% million hectares). Almost three-fourths of commercial timberland is in the East.

Of commercial timberland, governments own only 28 percent, including **18 percent in National Forests (see figure 7-3)** and 5 percent in State forests; the Federal portion is mostly in the West. Most commercial timberland is owned by the timber industry, farmers, and other private entities. Over one-half of timber industry holdings are in the South. Nonindustry landowners number in the millions, and their holdings often are small; most farmer-owned timberland is east of the Mississippi River (300).

Timberland Productivity-Xn ecological terms, productivity is the rate at which solar energy is converted during photosynthesis into living biomass. For timberland productivity, the U.S. Forest Service uses a more restricted measure-the amount of industrial wood that can be grown per year in fully stocked natural stands (300). It estimates that the overall average for U.S. timberland is around 3.2 cubic meters of woody biomass per hectare per year.

About one-third of U.S. timberland (i.e., less than one-fourth of **all** U.S. forests) exhibits average productivity rates of over 5.6 cubic meters per hectare per year. The timberlands with the very highest rates are primarily in the South and West: 1) pine, oak, hickory, and cypress in the Southeast and Mississippi River delta; 2) Douglas fir, hemlock-spruce, and red alder in the Northwest; and 3) redwood, spruce-fir, western hardwood, and ponderosa pine in California (299, 300). High productivity timberland also occurs in the oak-hickory, maple-beech-birch, and aspen-birch forests of the North.

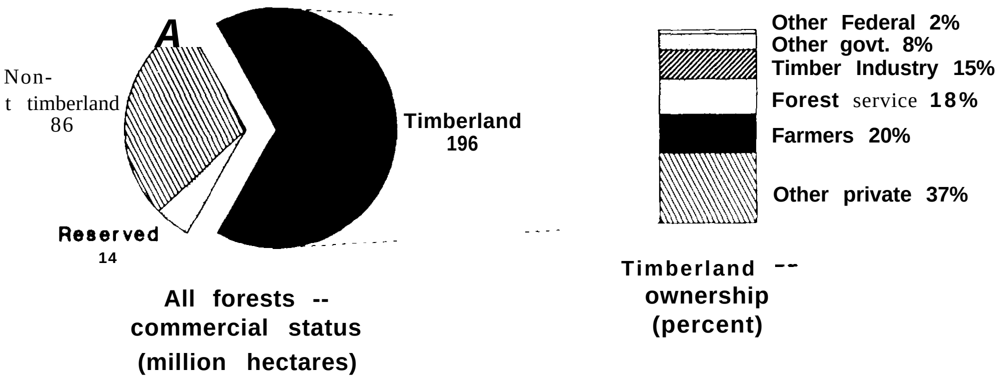
Two-thirds of timberlands exhibit only moderate or low productivity, but their abundance makes them commercially important; national forests tend to be located in these areas. Other forests that are not considered timberland can be harvested, but generally not for industrial wood (300). Two areas account for almost three-fifths of this "nontimberland"—the spruce-fir forests of interior Alaska and the pinyon-juniper forests of the Rockies.

in U.S. forests is below ground) (44, 60, 93, 253, 295).

Use of these techniques will vary with land ownership and forest size. Private nontimber industry owners, generally with smaller holdings, seem likely to use less intensive techniques, while timber industry landowners seem likely to use a combination of techniques. Together, implementing these practices on private lands might increase carbon storage by 10 million metric tons per year in 2000 (0.8 percent of U.S. CO_2 emissions) and by 40 million metric tons per year in 2015 (3.1 percent of U.S. CO_2 emissions) (see table 7-l), at an annualized cost in 2015 of around $150 to $200 per ton C (based on data in app. A). Intensive management on public lands seems-less likely because it would involve government expenditures at a time when budgets in general are being reduced, some expenditures on public lands are being criticized (e.g., roads for below-cost timber sales), and resources for maintenance are not always sufficient.

Nontimber Industry-About 112 million hectares (57 percent) of U.S. commercial timberland consists of relatively small parcels held by private nontimber-industry owners, including farmers (see box 7-B and figure 7-3). Full stocking on these lands might increase growth rates for commercially valuable wood by an average of about 0.5 metric ton C per

Figure 7-3--Commercial Status of All U.S. Forests (by hectares) and Distribution of Timberland Ownership in 1987



Two-thirds of all U.S. forests are considered timberland (i.e., forest producing or capable of producing "industrial" wood at a rate of 1.4 cubic meters or more per hectare per year). Most of this is commercially available for harvesting, but some is in parks and wilderness areas and is "reserved" from commercial harvest. Of commercially available timberland, the private sector owns 72 percent and the public sector owns 28 percent. ("Other govt." refers to Bureau of Land Management, Native American, and State and local government lands.) The remaining one-third of U.S. forests is considered nontimberland.

SOURCE: U.S. Forest Service, *An Analysis of the Land* Situation *in the United States: 1989-2040, A Technical Document Supporting the 1989 RPA Assessment,* General Technical Report RM-181 (Fort Collins, CO: U.S. Department of Agriculture, 1989); U.S. Forest Service,*An Analysis of the Timber Situation in the United States: 1989-2040, Part/: The Current Resource and Use Situation,* Draft (Washington, DC: U.S. Department of Agriculture, 1989).

hectare per year.[15] If a program encouraging the ‘se of additional management techniques on one-third of nonindustry timberland (i.e., 37 million hectares) began in 1995 and was carried through 2015, then additional carbon storage could amount to about 4,6 million metric tons in 2000 and 20 million metric tons in 2015.[16] However, this does not account for carbon emissions from the removed vegetation, some of which may be burned onsite or left to decompose.

Timber Industry-The timber industry owns 29 million hectares (15 percent) of commercial timberland (see figure 7-3). This land should be amenable to intensive management because it often is on more productive sites and because large holdings should provide economies of scale for such management. Intensive management on a large scale, though, will require that planting, site preparation, maintenance, and other practices be conducted on an unprecedented scale. Since some research indicates that large increases in timber growth rates are possible in some circumstances (see above), OTA assumes that the average productivity of affected systems might double, i.e., increase by an average of 1 metric ton C per hectare per year.[17] If a program to encourage intensive management on two-thirds of industry timberlands (i.e., 20 million hectares) began in 1995 and was fully realized by 2015, then additional carbon storage could amount to 5 million metric tons in 2000 and 20 million metric tons in 2015.[18]

[15] Marland(155) estimated, based on 1977 data, that the average carbon storage rate for all U.S. timberland was 0.82 metric ton C per hectare per year, and that the potential average rate for fully stocked forests was an additional 0.53 metric ton C per hectare per year. Average growth rates have not changed significantly since then, and the average growth rate in 1986 for nontimber industry private lands was essentially the same as the average rate for all U.S. timberland (300).

[16] A program of such magnitude seems reasonable, since about 2 percent of the volume of commercial timber on nonindustry lands is harvested annually (based on data in ref. 300).

[17] Higher growth rates occur under experimental conditions; e.g., the average total growth rate of genetically improved loblolly pine on one ‘igh productivity site was 3 metric tom C/ha/yr over a 35-year period (based on data in refs. 18, 19). OTA assumes that average increases might be 1 metric ton C/ha/yr because of questions about maintaining high growth rates over long periods, and because the net effect depends on the extent of CO_2 emissions from harvesting and the disposition of harvested wood (box 7-A).

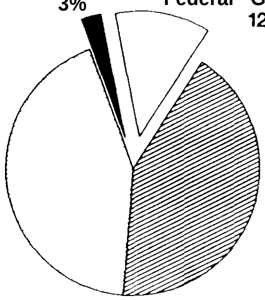
[18] A program of such magnitude seems reasonable, since about 5 percent of the volume of commercial timber on timber industry lands is harvested annually (based on data in ref. 300).

Bringing 1 million hectares yearly under intensive management would require dedicating all current replanting efforts to such management (since planting seedlings or young trees on prepared sites usually is required). Most forest regeneration in the United States occurs naturally, but about 1.22 million hectares were intentionally planted in fiscal year 1989, compared with 1.37 million hectares in fiscal year 1988 and 1.23 million hectares in fiscal year 1987 (301, 302, 303).[19] In general, 80 percent of the planting has been in the South and 85 percent has been on private land (see figure 7-4).

"New ***Forestry"*** Practices—Planners also need to consider how forests might be affected by future climate changes, however uncertain these changes might be (see box 7-Din ''Policy Options' below). For example. monoculture may be more susceptible to damage from increased pest outbreaks than are natural forests with a mosaic of species and ages, although some pests require a mixture of age classes (220, 236, 237, 246, 275). Some evidence suggests that harvesting practices that fragment Douglas fir forests into smaller parcels can increase pest problems (200). Caution is needed, though, in making generalizations (200, 237). For example, virulent diseases such as chestnut blight and insects such as gypsy moths have devastated natural, heterogeneous forests.

Some ecologists suggest that making commercial timberland more adaptable to future climate changes, preserving biological diversity, and allowing timber commodity production will require ''new forestry' management based on harvest patterns that maintain the characteristics of old-growth forest ecosystems (79, 83, 200, 236). For forests under multiple-use management, for example, this would entail leaving standing dead trees, fallen logs, and other woody debris[20]; developing stands of mixed composition and structure; using harvesting patterns that do not fragment forests into numerous small parcels; and using harvesting and reforestation methods that do not greatly disturb the soil. This approach has been tried on a small scale in the Pacific Northwest; more research is needed to determine whether its timber production and resource conservation goals can be meshed successfully in different situations.

Figure 7-4-Reforestation of U.S. Timberlands by Ownership Category, Fiscal Year 1989



SOURCE: U.S. Forest Service, *Report of the Forest Service, Fiscal Year 1989* (Washington, DC: U.S. Department of Agriculture, February 1 990).

Restrictions on Commercial Harvests-One unresolved issue is whether it is better to harvest forests, sequester some of the carbon in products, and replant the harvested area, or to leave forests alone over the short term. Restricting commercial harvesting to avoid releasing CO_2 has been suggested. However, demand for wood and paper products will continue to be high-so if harvesting is restricted on a large scale, wood will have to come from elsewhere and be used more efficiently, or energy will have to be used to extract other materials and manufacture substitutes for wood products. Moreover, even unharvested forests change over time and can emit CO_2 (see box 7-A).[21] An alternative to large restrictions in general could be to assess the feasibility of ''new forestry' practices (see above) that might allow some accommodation between timber production and natural resource conservation goals.

[19] These reforestation rates refer to the number of hectares planted, not the number of surviving trees. The 1988 plantings involved nursery production of 2.3 billion seedlings (over one-half from private nurseries).

[20] Although this could increase fire risks, or increase CO_2 emissions from subsequent decomposition, compared, for example, with burning the wood in place of fossil fuels.

[21] Over the long term, harvesting the wood and permanently sequestering it or using it on a sustainable basis to replace fossil fuels could provide bigger reductions in carbon emissions.

Another possibility is smaller scale restrictions. For example, restricting the harvesting of "old-growth" forests can be justfiled for a variety of reasons, including the opportunity for the United States to demonstrate leadership in global efforts to preserve biodiversity and halt deforestation of virgin forests. Its effect on carbon emissions, however, would probably be relatively small (see box 7-C).

Increasing End-Use Efficiency and Recycling—Other practices involve increasing end-use efficiency and conservation in the forest products industry and its products (similar to increasing efficiency in other sectors; see chs. 3 through 6). OTA (274) discussed how the forest products industry could use wood more efficiently to make products and how end-use efficiencies of wood products could be increased (e.g., improving building construction designs, using efficient fuelwood burners).

Recycling of paper and paperboard products (e.g., newsprint, printing and packaging paper, cardboard) has received great attention because of municipal solid waste problems (281). Recycling these products can reduce the use of both virgin fibers and energy in making some new paper products, and help divert some municipal solid waste away from landfills (91, 281, 296). If other demands for wood fibers remain constant, then some trees might be left unharvested because of recycling efforts; they would continue to store carbon for some time.

Whether recycling offsets carbon emissions, however, depends on what happens to paper in landfills. Some research suggests that landfilled paper may not decompose into either CO_2 or methane for decades (see box 7-A). If true, then sequestering paper in landfills might be better than recycling in terms of avoiding greenhouse gas emissions, at least in the short-term. However, since methane is a potent greenhouse gas (see ch. 2), then recycling might be preferred if landfilled paper does contribute to methane emissions. But whether the methane emitted from landfills is derived from paper or from yard and food wastes is unknown. Regardless, methane from landfills can be collected and used as an energy source (see box 3-A in ch. 3), and recycling itself involves emissions of CO_2 from transporting and processing recovered paper.

New Forests and Trees

General Afforestation and Conservation Reserve Program

Afforestation—planting trees on land that has never supported forests or where forests have been cleared for decades or more--offers opportunities to store carbon in new trees and help stabilize soil in many areas. The extent of carbon storage depends on factors such as soil conditions, rainfall, types of trees, whether or not trees are harvested, and maintenance.[22] Most U.S. cropland being taken out of production (see below) is highly erodible, and some of it may exhibit soil degradation from mineral depletion, so not all is suitable for tree planting.

In general, trees planted on unforested lands are unlikely to be intensively managed (except for biomass fuel crops; see "Planting for Biomass Energy" below), in contrast to plantations established to reforest harvested timberlands. A cautious assumption is that average growth rates for the woody portion might be similar to those on unmanaged timberland, about 1 metric ton C, per hectare per years.[23] As noted above (see ''Increasing Productivity' '), whether this means that total productivity increases is unclear. And, as with intensive management techniques, tradeoffs can include N_20 emissions from fertilization and CO_2 emissions from soil disturbance.

To estimate potential carbon savings, it is reasonable to examine current tree planting in the Conservation Reserve Program (CRP) and the potential for planting on non-CRP lands. Through 10-year contracts with farmers, the CRP aims to plant trees on 2.3 million hectares of cropland (as part of its overall goal of removing 16 to 18 million hectares of cropland from production; see box 7-E in "Options for U.S. Forests" below). If this goal is met by 1995 and trees are retained through 2015, and if annual growth rates average 1 metric ton C per hectare, then about 2.3 million metric tons C would be stored per year, including both 2000 and 2015. For non-CRP lands,

[22] The drought of *1988,* for example, killed about 250 million tree seedlings on 140,000 hectares of forest plantations (205).

[23] The average growth rate for the commercial wood on existing U.S. timberland is 1 to 2 short tons C per hectare per year (300). Similarly, the average growth rate exhibited by spruce-fir forests with natural regeneration on an average site was 1.4 short tons C per hectare per year over a 65-year rotation (1 8). However, growth rates could be higher in some areas, particularly where croplands are more productive than average timberland.

Box 7-C--Harvesting Old-Growth Forests

The Debate About Old-Growth Forests—"Old-growth" forests generally have a mixture of large old trees (including dead "snags"), layers of small-and medium-sized trees, and fallen logs and other woody debris on the ground (250, 326). However, disagreements exist about exact definitions for different regions and a result, about the extent and location of remaining old-growth forests. Probably less than 2 percent of all U.S. forest land is still old-growth. Almost all old-growth on private land has been cut. Ramaining stands are primarily in western national forests, particularly Douglas-fir stands in the Pacific Northwest and spruce-hemlock stands in Alaska's panhandle (mostly in Tongass National Forest). Douglas-fir is the predominant commercial species in the Pacific Northwest.

Environmental groups support restrictions on future harvesting because most old-growth has already been cut and the remainder, mostly on public lands, affords nontimber values such as biological diversity, watershed protection, fisheries, and wilderness. They feel these values arc inadequately protected by national forest planning processes.[1] Much of the debate has centered around the northern spotted owl, an "indicator" species that is now listed by the U.S. Fish and Wildlife Service as threatened throughout its range.[2]

The timber industry contends that sufficient old-growth (over 0.4 million hectares of stands over 200 years old) is already protected in wilderness areas, national monuments, and national parks; that some old-growth must be harvested to meet demands for products such as special veneers and decking; and that restrictions will cause losses of jobs and of revenues to counties from sales on Federal lands (25 percent of gross receipts from timber sales on Federal lands is allocated to counties for road construction and education). Along with the USFS, it believes current planning processes should not be interrupted (250, 251, 309).

Carbon Dioxide and Old-Growth---Old-growth forests contain large amounts of carbon (over 400 tons per hectare in some areas of the Pacific Northwest) but exhibit little or no net growth or additional carbon storage. In contrast second-growth forests contain less carbon but continue to take up and store carbon.

One model (93) projected that carbon storage m second-growth forests in the Pacific Northwest would not approach the level of carbon stored in old-growth forests for at least two centuries, and that converting old-growth to second-growth reduced net carbon storage on a forest site by a total of 305 metric tons per hectare over a 60-year rotation.[3] Current harvesting rates for old-growth maybe around 10,000 to 25,000 hectares per year.[4] Using the model's projections and assuming that harvesting is not increased elsewhere, the net effect of not clearing this land would be to hold about 3 to 8 million metric tons of carbon that would have otherwise been released and not resequestered during the course of a 60-year rotations

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[1] National Forest planning processes are outlined in the Multiple-use Sustained-Yield Act of 1960, Forest and Rangeland Renewable Resources Planning Act of 1974, ad National Forest Management Act of 1976. Bureau of Land Management planning is addressed in the Federal Land Policy and Management Act of 1976.

[2] While the Fish and Wildlife Service was undertaking its listing determination, the U.S. Forest Service and the Bureau of Land Management were sued to halt harvesting in spotted owl habitat. Ensuing court actions would have halted timber sales of more than 2 billion bored feet of timber (144, 309). In the fiscal year 1990 appropriations for the Interior Department (Public Law 101-121), Congress modified the court actions so that some old-growth is protected and some sales can be offered, although sates still are expected to decline by about 0.7 billion board feet per year.

[3] Assumptions in the model include: 1) 42 percent of the boles are converted to building structural components (with 2 percent annual replacement of structures); 2) repeated harvesting does not reduce long-term site productivity; 3) net productivity of second-growth bole wood and bark peaks at 30 years, at 8.5 metric tons of C per hectare per year; and 4) changing climatic condition do not affect processing rates. The model also assumes that old-growth forests stay relatively constant, but old-growth trees eventually die and release carbon; even so, this would primarily affect the timing of emissions—i.e., commercial rotations would have "pukes" every 60 or so years, whereas old-growth stands might not exhibit significant emissions for centuries.

[4] The Wilderness society (326) estimated that 25,000 hectares are harvested yearly. However, using a more restricted ecological definition, as the society did elsewhere (324), leads to the assumption that perhaps 10,000 to 15,000 hectares are harvested yearly.

[5] Other factors also win influence these estimates. For example, if harvested wood is used in place of fossil fuels for energy production, then the net effect would be lower. Whether nutrient availability is sufficient to maintain carbon storage rates during a series of harvest rotations is unknown; fertilization might help, but it would result in N_2O and CO_2 emissions (see ch. 8). Whether higher average temperatures (from climate change) might decrease the rate of microbial decomposition (and associated emissions) of debris m them forests, or whether drier conditions might counter this, also is unknown

***Economic Effects of Restrictions*—**Estimates about how restrictions would affect local economies in the Pacific Northwest and in Alaska are controversial and vary widely (57, 144). From a historical perspective, though, the Pacific Northwest timber industry generally has been declining since the early 1970s, and employment is expected to continue to fall because of improvements in mill automation (272). The Wilderness Society (325) considers mill automation and a general decline in the availability of timber in general to be the most important factors in overall job losses in the Northwest.

The decline in domestic timber availability is partly related to exports of unprocessed logs, harvested mostly from second-growth stands on private and State lands.[6] These exports are attractive to companies because of higher overseas market prices and accounted for 39 percent by value of U.S. wood exports from 1980 to 1988; 42 percent by value went to Japan (143). According to industry representatives, Japanese trade barriers discriminate against value-added U.S. wood products (49, 148).

Linkages-The likely outcome of the debates and negotiations that have taken place over the last few years-particularly since the U.S. Fish and Wildlife Service must still decide how much critical habitat is needed to support viable spotted owl populations—is a plan that provides for conservation of some additional old-growth forests and for some harvesting. Although this would not preserve all remaining U.S. old-growth forests, it still could enhance U.S. efforts to reduce tropical deforestation, provide for better tropical forest management, and conserve biological diversity, particularly if international forestry protocols (see ch. 1) are negotiated. This also could be linked with efforts to change U.S. harvesting patterns so that more old-growth characteristics are retained (see "New Forestry Practices" above), as well as with efforts to ensure that the most valuable timber is used for relatively long-lived products.

One way to stem domestic job losses might be to ban or tax exports of unprocessed logs from private and State lands, to encourage domestic processing of these logs to obtain the added value of finished products (see "Options for U.S. Forests"); we also can continue to improve the end-use efficiency of processing to obtain more from each log (see "Increasing End-Use Efficiency and Recycling" above). Plans to set aside additional old-growth stands on Federal lands also should consider provisions to help compensate loggers and communities for economic impacts (e.g., see 86, 143).

[6]Congress has prohibited, in the annual Interior Department appropriations, exports from Federal lands. Some loopholes allow ''substitution' (i.e., when private landowners export timber from their lands and then purchase Federal timber for use in their mills).

economic opportunities for tree planting may exist on around 30 million hectares.[24] If a program to plant trees on 30 million hectares began in 1995 and was maintained through 2015, then additional carbon storage (assuming the same growth rates) would amount to 7.5 million metric tons in 2000 and 30 million metric tons in 2015. OTA estimates that the CRP and General Afforestation together might offset 0.8 percent of 1987 emissions in 2000 and 2,3 percent in 2015 (see table 7-l), at an annualized cost in 2015 of around $35 per ton C (based on data in app. A).

This would require planting 1.4 million hectares of unforested land per year, slightly more than current rates on previously forested lands (see ''Increasing Productivity' above) .25 For unforested lands, the highest planting rate under previous Federal programs was 0.2 million hectares per year, from 1957 to 1961 in the Soil Bank Program (which, like the CRP, paid farmers to retire land from crop production) (40, 168, 301).[26] Under the CRP, current tree planting rates average 0.25 million hectares per year, with a total of 0.9 million hectares planted as of March 1990 (286).

[24]The USFS estimates that opportunities exist on up to *33* million hectares of crop and pastureland (170, 305). After accounting for the CRP, the total would be around 30 million hectares. For comparison, about 350 million hectares might be available in the entire temperate zone, including over 250 million hectares in the U.S.S.R. and much smaller amounts in Canada, Europe, and China (54, 102). In the U. S. S.R., however, only 5 million hectares had been set aside as of 1984 for silvicultural treatment and much of the remainder was considered relatively inaccessible (102, 288), and whether current management can be maintained has been questioned (12),

[25]In 1989, approximately 225 million trees were planted on Federal lands (305). The President's proposed "America the Beautiful" tree-planting program (see "Options for U.S. Forests" below) called for planting 1 billion trees on 0.6 million hectares of rural land per year and 30 million trees per year in communities (191, 304).

[26]Under the Shelterbelt Project, run by the USFS from 1935 to 1942, about 100,000 hectares were planted, including 18,000 miles Of shelterbelts, and a chain of tree nurseries was developed from Texas to Canada (52).

CRP enrollment varies regionally, depending on markets for food crops, promotion by State agencies, and potential economic returns from trees (59, 169, 271).[27] Timber becomes more valuable after its first decade or so of growth, which could enhance retention of trees for a few years.[28] The 1985 Food Security Act (which established the CRP) could make it more difficult to reconvert to cropland, through its swampbuster, sodbuster, and conservation compliance provisions (168) (also see ch. 8).

Planting for Biomass Energy

Unforested lands or even some previously forested lands also could be planted with quick-growing tree crops that are harvested and used as a renewable ''biomass energy' fuel.[29] During the late 1980s, forest residues and wood wastes supplied about 3 to 4 percent (2.5 to 3.0 quads) of U.S. energy use, with one-third used at residences and two-thirds by industry. Biomass crops might eventually supply double this amount (273, 342); however, only about 3.7 quads were considered economically recoverable from biomass crops in the late 1980s (100).

The U.S. Department of Energy has sponsored research since 1978 on producing ''short-rotation' woody crops that could be economically competitive with fossil fuels (290, 342). The research involves intensive management (e. g., genetic selection, site preparation, fertilization) of fast-growing species, and harvesting on a 3- to 10-year cycle. Average growth rates of about 4 to 7 metric tons C per hectare per year have been attained in trials, and plots of hybrid cottonwoods have exceeded the goal of around 9 metric tons C per hectare (99, 208, 343). Current research is addressing genetic improvements in disease resistance and energy qualities, species adaptability, and economics (46, 187, 343),

Questions about short-rotation crops bear on:

- maintenance of productivity over long periods;
- long-term effects of repeated harvesting on soil debris, nutrients, and erosion;
- effects on monoculture of pest and disease outbreaks; and
- availability of advanced propagation and harvesting technologies (44, 112, 343).

More fertilizer use would lead to CO_2 emissions from its manufacture and possibly N_2O emissions after application (see ch. 8). Other tradeoffs include CO_2 emissions from soil disturbances (e.g., during harvesting) and from energy use in planting, harvesting, transporting, and processing.

OTA assumes that growth rates for the harvestable biomass in large, long-term operations might be 3 metric tons C per hectare per year.[30] How much land might be dedicated to biomass crops is unclear; only 7,500 hectares were in full-scale production or research trials in North America in 1989 (342).[31] The amount of unforested U.S. land economically available for planting in general might be 33 million hectares (see "General Afforestation" above), but this could be higher if biomass becomes competitive with other energy sources. However, the infrastructure for a large biomass industry (e.g., plantations, equipment suppliers, processing plants, etc.) needs to be developed (1 12). Whether landowners would opt for biomass crops with unproven market performance, as opposed to subsidized tree planting programs (e.g., the Conservation Reserve Program; see ''General Afforestation' above) is unknown.

As a moderate estimate, if a program to plant 0.5 million hectares per year for biomass energy crops began in 1995 and was carried through to 2015 without affecting other planting efforts, then additional carbon storage in the harvestable biomass would amount to 7.5 million metric tons per year in 2000 and 30 million metric tons per year in 2015. The energy content of this biomass would equal about 1.2 quads per year in 2015. This would require doubling cur-rent rates for all planting on unforested lands, to about one-third the current rate on forested lands. Not all of this storage would actually offset CO_2 emissions. The net effect would depend on:

[27] About 85 percent of the planting has been in the Mississippi Delta and the Southeast; most remaining eligible (i.e., highly erodible) cropland is concentrated in arid regions of the Plains and Rocky Mountains that are less amenable to trees (169, 299).

[28] Over 85 percent of the acreage planted in the Soil Bank program retained trees two decades later (4, 129), but many trees planted during the Shelterbelt program have been cut as trees aged and marginal cropland was cultivated.

[29] Nonwood vegetation (e.g., grass and legume herbs, crop residues, ethanol feedstocks) also is suitable for biomass energy.

[30] This assumption is lower than what has been achieved experimentally, but it is three times greater than average growth rates on unmanaged lands. It accounts for uncertainties discussed above and for nonproductive areas (e.g., roads, fences, streams) that typically are not present in test plots but that would be in larger operations; it also includes carbon storage in the soil and in nonindustrial wood components (e.g., roots, twigs).

[31] Trials also are being conducted in at least seven European countries (92).

- relative emissions of CO_2 (and methane) from energy-equivalent units of biomass and fossil fuel;
- CO_2 emissions during harvest and transport of crops;
- what and how much fossil fuel is actually supplanted by biomass; and
- whether new crops are grown to replace those used for fuel.

For example, using biomass to replace coal in boilers would offset more emissions than using it (with an additional conversion step) to replace transportation fuels such as gasoline (which have less carbon and fewer emissions per unit of energy than coal). Given these uncertainties, OTA assumes that biomass fuels can offset carbon emissions from an energy-equivalent amount of fossil fuel by, on average, one-half of the amount of carbon stored in the harvestable portion of the crops. For the planting program described above, this would amount to about an offset of 4 million metric tons in 2000 (0.3 percent of 1987 emissions) and 15 million metric tons in 2015 (1.2 percent of 1987 emissions) (see table 7-1) at an annualized cost in 2015 of around $67 to $133 per ton C (based on data in app. A).[32]

By 2015, much of the additional wood grown through intensive management (as described in "Increasing Productivity" above) will be available for use as biomass fuel as well. Over the 20 years, the management practices described earlier will have yielded additional wood storage containing about 25 quads of energy. To continue to gain carbon benefits from the increased productivity, the wood must either be used as biomass fuel (on a sustainable basis) or cut and permanently sequestered in some way.

Urban Tree Planting

Trees and shrubs in urban areas store some carbon and, once they are large enough, can reduce some of the heat load on adjacent buildings in the summer and shelter them from wind in the winter (1, 2, 110, 160, 197). Trees also help reduce the "heat island" effect (i.e., increases in average ambient air temperatures) common in cities.

Photo credit: American Forestry Association

Many groups around the country sponsor tree-planting efforts in their communities. Urban trees provide numerous benefits, including beauty, carbon storage, shading of buildings, and reduced "heat island" effects.

One modeling exercise estimated that planting 100 million trees around air-conditioned homes and small commercial buildings in the United States might save 8.2 million metric tons C per year in avoided fossil fuel use for cooling; carbon storage in the trees might increase this by 5 to 10 percent (1).[33] However, these estimates are subject to uncertainties such as feasibility of field application, potential for feedbacks on local climate (e.g., evapotranspiration from trees, changes in albedo), and potential for CO_2 or methane emissions from the decomposition of additional leaves.

[32] The Department of Energy estimates that short-rotation woody crops could offset 3 to 5 percent of current annual U.S. CO_2 emissions, assuming current production and conversion technologies, and up to 35 percent assuming technology advancements (e.g., higher conversion efficiencies and higher growth rates) and using a high estimate of land availability (343).

[33] Assuming that one-half of peak demand (i.e., when energy is most often used for cooling) is supplied by coal and one-half by oil and gas.

If a program to plant 100 million trees near buildings begins in 1995, and it takes trees about 10 years to reach a large enough size to provide sufficient shade for reducing heat loads, and if energy savings are as estimated by the model, then carbon savings might amount to about 1 million metric tons in 2000 (i.e., from carbon stored in growing trees, but no energy savings yet from shade because the trees are too small) and about 9 million metric tons in 2015. This would offset about 0.1 percent of 1987 U.S. emissions in 2000 and 0.7 percent in 2015 (see table 7-l), at an annualized cost in 2015 of around $180 per ton C (based on data in app. A).

A critical issue in any tree-planting program (whether the CRP or an urban tree program) is proper planting and maintenance. Many urban trees, particularly along roadsides but also in parks, suffer from inadequate root space, mechanical stresses, air pollution, and poor maintenance (5, 22, 115, 127, 166, 167). Unfortunately, budgets for urban tree maintenance have declined in most cities, and trees are being lost faster than they are being replaced (166, 167).[34] Maintenance and other costs can include damages from falling trees; destruction of pipes; and labor costs of pruning trees, removing trees that reach the end of their useful lives, finding and marking underground power lines in highly urbanized areas, and removing leaves from roadsides or parks.

MANAGEMENT PRACTICES IN TROPICAL FORESTS

Several management and land-use practices could help reduce CO_2 emissions associated with tropical deforestation (see table 7-2), and provide other benefits such as protection of soils, watersheds, and biodiversity. While the theoretical potential for reducing deforestation and CO_2 emissions seems relatively high, each practice faces obstacles in the form of social attitudes, counterproductive development policies, and population pressures, not to mention costs; these are discussed below in "Options for Tropical Forests."

Providing Alternatives to Deforestation

Agroforestry and "Sustainable" Agriculture

Traditionally, shifting cultivation involved clearing forests (typically on upland soils), producing crops for a couple of years, abandoning the land for a ''fallow' period that allowed nutrient levels to rebuild, and then recultivating it two to three decades later (72, 164, 207, 232, 275, 292).[35] This did not greatly affect tropical forests until recently. In the last few decades, however, many people have migrated from long-established farming areas into forest areas, often along logging access roads, and they have tended to use shorter fallow periods. Population pressures, lack of land tenure, agricultural mechanization in some areas, and/or large-scale colonization schemes have contributed to this migration (62, 68, 107, 131, 174, 207, 231, 275). As a result, shifting cultivation accounted for perhaps 45 percent of deforestation in 1980 (264).

Land-use practices such as agroforestry or "sustainable' agriculture, which tend to be small-scale and adaptable to variable conditions and traditional farming systems, might lessen some of these pressures. More research is needed, though, to evaluate their effects on forest conversion rates; it is unclear how readily they will be adopted (especially without financial and technical assistance) and how many people they can support in a given area (6, 61, 151, 176, 295).

Agroforestry--Agroforestry means growing trees and shrubs along with annual crops and/or livestock (e.g., in windbreaks, along perimeters, intercropped in fields), at the same time or sequentially. In principle, it can help store carbon, improve soil quality and reduce nutrient losses, provide food and other nonwood products and shade, and increase fuelwood supplies. While it has been practiced for centuries or millenia, most formal research has been conducted only in the last decade or so.[36]

Some projects initiated by local farmers and peasants (with and without outside assistance) have been successful and have been copied by others; other projects are in early stages (43, 335). In

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[34] In 1986, City budgets for planting and maintenance totaled about *$425* million, with average expenditures of $11 per tree, but this was nOt adequate for proper maintenance (115). Cities may contain over 600 million trees (167); while some may not need yearly maintenance, these data suggest that proper planting and maintenance might require several billion dollars per year nationwide.

[35] Conversion of forests t. permanent cropland has occured more often in nonmountainous, lowland areas; it may be a more important cause Of deforestation in some areas, for example in much of Africa.

[36] E.g., see refs. 6, 14, 72, 85, 133, 151, 176, 180, 181, 182, 185, 186, 192, 207, 211, 243, 254, 260, 279, 314, 319, 329, 339, 3@.

Table 7-2—Tropical Forest Management: Potential Percent Offset of Estimated 1989 Carbon Emissions From Deforestation, for 2000 and 2015

Management practice	Assumptions[a]	Million metric tons C in 2000[b]	Percent offset from 1989 deforestation levels by 2000[c]	Million metric tons C in 2015[b]	Percent offset from 1989 deforestation levels by 2015[c]	Examples of other benefits
Alternatives to deforestation:						
Agroforestry	50 million ha by 2000, 200 million ha by 201 5; net storage 0.1-1 metric ton C/ha/yr	5-50	<1-2%	20-200	1 -7%	Soil and watershed protection, biodiversity
"Sustainable" agriculture	0.5 million ha/yr; see text	100	4%	100	4 %	Soil and watershed protection, biodiversity
Reduced cattle ranching	Reduce conversion by 1 million ha/yr by 2000; by 2 million ha/yr by 2015	100	3-4%	200	7%	Soil protection, biodiversity, local climate effects
Improved cookstoves	300 million people by 2000, 1 billion people by 2015; 40% less fuelstove	15-30	1%.	50-100	2-4%	Increase time for social, educational activities
Managing existing forests:						
Nontimber products	(see text)	NE[d]	NE	NE	NE	Soil and watershed protection, biodiversity
Improved timber harvesting	(see text)	NE	NE	NE	NE	Biodiversity, soil and watershed protection, local climate benefits
Managing new forests:						
Reforestation	Double rate to 2 million ha/yr; storage 5 metric tons C/ha/yr	50	2%	200	7%	Increase economic productivity, restore topsoil

[a]See text for greater detail; in general, assumptions do not directly reflect economic feasibility.
[b]Accounting for gradual implementation over a 25-year period; i.e., some planting and growth or other management occurs in year 1, but some does not occur until year 25.
[c]Percent of high estimate of 2.8 billion metric tons C/yr from tropical deforestation (see text and figure 7-1); individual percentage offsets are not additive.
[d]NE = No estimate.

SOURCE: Office of Technology Assessment, 1991.

Pho ed

cu g bu g od g co pl do g
pe g me me Th pl Th be ut ed
cu ed ma g cades—ma pl g m bl ed g
og g g g

Guatemala, for example, thousands of farm families are planting a mix of tree species to produce poles, fodder, fuelwood, and fruits and other crops, and to stabilize slopes (260, 339).[37]

While agroforestry is promising, more and broader research is needed (6, 14, 130). Relatively few projects have been conducted in wet lowland tropical forests, on degraded forest lands, or on most major soil types. Leguminous trees such as acacias and leucaena have justly received attention, but research is needed on other trees (1 16, 151, 315, 3 17). Other constraints include lack of: land tenure for peasants, local involvement in planning, markets for products, and incentives to sustain projects once official assistance ends (6, 14, 37, 43, 89, 151, 157, 176).

Published measurements of carbon storage in the woody biomass of trees in agroforestry systems range from 0.3 to 4 metric tons C per hectare per year (54).[38] Most systems have short rotations, and harvested crops generally are used in ways that quickly lead to CO_2 emissions, but some carbon is stored in durable wood products that may last for decades and some trees are retained as “live” fencing. The net effect thus might be carbon storage ranging from 0.1 to 1 metric ton C per hectare per year.[39] If a very ambitious program were begun in 1995 to have 200 million hectares (one-fourth the estimated cropland in tropical developing countries; see ref. 338) in agroforestry by 2015, carbon storage would be about 5 to 50 million metric tons in 2000 (1 to 2 percent of 1989 emissions) and 20 to 200

[37] The impetus and some funding ($2 million) for this is from Applied Energy Services, an American firm aiming to offset CO_2 emissions from a new coal-fired power plant in Connecticut. This is the first forestry-related project designed to offset emissions from a particular industrial source. In April 1990, the Netherlands budgeted a similar project in Bolivia, Peru, and Colombia, to offset emissions from two planned coal-fired plants.

[38] These would be higher if foliage, fine branches, and below-ground carbon were included.

[39] Assuming that: 1) two-thirds of harvested wood is stemwood and one-fourth of this is stored in durable products; 2) some trees are retained as live fencing; but 3) the majority, perhaps three-fourths or more, of trees and harvested wood is used in ways that quickly lead to CO_2 emissions.

Photo credit: W Parham

Agroforestry can take many forms, including interspersing various crops. This shows a field in China's southern Yunnan Province planted with rubber trees and tea plants. The government's Xishuangbanna Tropical Botanic Garden is experimenting with agroforestry in this area to restore degraded lands and provide crops that can be sold or used directly by local people. Other crops include peanuts, pomelos, coffee, cocoa vanilla, pineapple, sugar cane, medicinal plants, and various nitrogen-fixing cover crops and firewood crops.

million metric tons in 2015 (1 to 7 percent of 1989 emissions) (see table 7-2), excluding savings from avoided deforestation.

"Sustainable" Agriculture-in an agricultural context, ''sustainable' generally refers to maintaining yields without impairing the land's long-term productivity.[40] "High-input" agricultural systems involve relatively high use of fertilizers and pest controls. Research in a few tropical forest areas has shown that such systems can produce high yields for several years, but they also require extensive sampling to determine appropriate fertilizer applications; this in turn requires technical assistance or training of local people (61, 64, 132,232, 321, 322). Most shifting cultivators and small rural farmers lack capital for such practices and access to assistance and training.

One alternative, ' 'low-input' ' agriculture, is designed to minimize use of purchased fertilizers and pest controls; emphasis is placed on locally adapted crops and on recycling nutrients (e.g., crop residues, manure). In the Peruvian Amazon, a 1-hectare experiment yielded seven continuous crops in a 3-year period and replaced an estimated 5 hectares of shifting cultivation before yields declined and the area was left fallow (23 1, 233).[41]

The long-term utility of such systems remains unproven. Nevertheless, if low-input systems could be initiated on 0.5 million hectares each year, they might save about 2 million hectares from shifting

[40] In a broader context, the U.N. general definition is to ''meet the needs of the present without compromising the ability of future generation to meet their own needs' (337).

[41] The experiment featured maximum residue return, no tillage, and minimal fertilizer use, but use of commercial herbicides and manual labor to control weeds.

cultivation each year. Perhaps 100 tons C are initially released from each hectare cleared by shifting cultivation.[42] If the land is allowed a fallow period, some CO_2 will be stored in regrowing forest vegetation, If this amounts to, for example, an average of 50 tons C per hectare over the next two decades, then the net effect-over the 25-year timeframe of this report-of leaving 2 million hectares of forest standing would be to avoid around 100 million metric tons of emissions per year (about 4 percent of 1989 emissions from deforestation) (see table 7-2).

Reduced Cattle Ranching

Large areas of tropical forest have been converted to pasture since the 1950s, particularly in Latin America (98, 204); globally, an estimated 3 to 7 million hectares have been converted to pasture per year (50). While some productive pastures have been maintained for decades in countries such as Costa Rica and Venezuela (29). some tropical forest soils are not well suited for livestock and only support a meager grass cover for a short period before weeds and inedible grasses invade (88, 98, 263). This has occurred in Southeast Asia and Latin America (264).

Reducing the annual forest-to-pasture conversion rate by 1 million hectares by 2000 and 2 million hectares by 2015 would avoid 100 million metric tons of carbon emissions in 2000 (3 to 4 percent of 1989 emissions) and 200 million metric tons in 2015 (about 7 percent of 1989 emissions) (assuming around 100 metric tons C are released per hectare cleared) (see table 7-2). Another benefit might also be a reduction in future methane emissions from livestock (see ch. 8). However, the economic costs of slowing conversion are unknown and the institutional and social barriers are likely to be enormous (see “Policy Options” below). At the same time, though, efforts also could be made to improve existing cattle ranching (e.g., by using better forage and grazing management) (242),

Use of Improved Cookstoves

The importance of fuelwood consumption as a cause of deforestation is unclear (1 14, 134). Cutting trees directly for fuel (especially to make charcoal) can cause local deforestation, for example in drier regions with open tree formations, in high montane areas, and near urban areas and along roadways (123, 134, 155). In many areas, though, cutting trees for fuelwood may be a more important cause of forest degradation than of deforestation.

End-use demand for fuelwood can be reduced by using better cookstoves. During the 1980s, some improved charcoal cookstoves with higher heat transfer efficiency than traditional stoves gained consumer acceptance in many countries (1 1), In Kenya, for example, an improved version of the traditional ‘‘jiko’ ceramic stove can reduce fuel use by 15 to 40 percent and pay for itself within a few months (11, 94, 192, 211, 268).

Annual fuelwood use for cooking might be on the order of 0.2 to 0.4 metric ton per capita.[43] If improved cookstoves reduced fuelwood consumption by 25 percent, a savings of 0.05 to 0.1 metric ton C per year per capita might be achieved. If 50 million additional households with 6 people per household (300 million people) used such stoves by 2000, then carbon savings would be around 15 to 30 million metric tons (1 percent of 1989 emissions) (see table 7-2). If 175 million additional households (1 billion people) used them by 2015, then carbon savings would be around 50 to 100 million metric tons (2 to 4 percent of 1989 emissions) (see table 7-2).[44]

Managing Existing Forests

Harvesting Nontimber Forest Products

Many nontimber forest products provide services and revenues to local people-e. g., nuts, herbal medicines, fibers, latex, fruits, oils, spices, fodder, palm thatch, bamboo, cork, tannin-but little has been done to estimate their value or to identify new products (47, 65,70,84,87,316, 317). In Indonesia, the minimum export value of such products in 1987

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[42] The amount of above-ground carbon varies with location and forest type, Closed tropical forests contain an estimated 138 to 192 metric tons C per hectare in aboveground biomass (25), but open forests contain considerably less (27). Fearnside (68a) estimated that Brazilian Amazon forests contain 106 to 124 metric tons C per hectare,

[43] Based on estimates for some developing countries that fuelwood used for cooking ranges from 8 to 18 Gigajoules per person (11), and on conversion factors of 1,054 joules per Btu and 55 pounds of carbon per million Btu (ch. 3).

[44] These estimates assume less fuelwood use rather than a shift of fuelwood to noncooking uses. Whether this is a fair assumption is unknown. Another question is whether any relationship exists between emissions from improved cookstoves and respiratory infections and chronic lung diseases, as has been suggested for older cookstoves (11, 134, 171,247, 248, 268).

was estimated at $238 million, more than 10 percent of the value of all log exports (47). In the Peruvian Amazon, net revenues from nontimber products on 1 hectare were estimated to be two to three times higher than revenues from harvesting commercial timber on a similar-sized plot (201, 202).[45]

However, because nontimber products tend to be marketed locally and in a decentralized manner, their value is generally hard to recognize and assess. In contrast, timber products receive greater government support, partly because they generate foreign exchange. High discount rates also enable entrepreneurs to obtain quick profits from intense timber harvesting (66, 135, 201).

Nontimber products have been promoted in a few cases by establishing ''extractive reserves' '—areas of standing forest in which products are extracted, usually with traditional methods. Such reserves have been established in Brazil for nuts and rubber, for example (211).[46] Their potential effect on CO_2 emissions cannot be estimated, however, without knowing how many people can be supported, establishment and maintenance costs, and transport and market opportunities for products. Today, rubber-tapping in the Amazon supports only a sparse population and already is heavily subsidized by the Brazilian government (65). In some cases, harvesting may even be nonrenewable (e.g., cutting palm trees to more easily obtain their fruits) (22). Nevertheless, extractive reserves can play a role in more integrated systems (e.g., with concurrent agroforestry in adjacent areas) .47

Improving Commercial Forest Management

Commercial logging, mostly in humid forests, affected an estimated 4.4 million hectares annually in 1980 (114, 264). Usually no more than 10 percent of tree species are commercially favored, and these typically are harvested by selective logging (i.e., ''high-grading' '). Exports of these trees have generated major revenues during the last few decades, particularly in Southeast Asia and Western Africa; roughly one-half of the exports have been to developed countries (175, 292).

How much commercial harvesting is conducted on a ''sustainable' basis is controversial.[48] In many areas, high-grading and lack of long-term management have depleted the most valuable trees, and harvesting has shifted elsewhere (214, 263). High-grading also often degrades forests by damaging or destroying noncommercial species and greatly reducing canopy cover (214, 215, 216, 263, 275). Thus, many developing countries have lost or are losing this revenue source.[49] In addition, logging roads open up new areas to migrating cultivators and ranchers.

Harvesting will continue, though, and research is needed on how to improve it. Research has been conducted in Southeast Asia and elsewhere on harvest techniques that minimize damage to remaining trees and on management techniques that enhance growth rates of favored species (66, 121, 154). In Costa Rica, a door manufacturer is trying different harvest techniques to assure a sustainable supply of mahogany in a project insured by the Overseas Private Investment Council (see ch. 9).[50]

Opportunities also exist to increase the use of lesser known species and of each harvested log (e.g., using residues for particleboard) (282). These efforts might increase returns from a given area and reduce pressures for harvesting other areas, but they also would encourage clearcutting. The history of commercial logging and reforestation in the tropics

[45]This ma, be a special situation because a large, nearby market for perishable fruits and the infrastructure for transporting and marketing the fruits already exist.

[46]In a similar manner, som, wildlife species threatened with extinction are being ''farmed' to provide revenues for local villagers, conserve habitats, and increase species population=. g., butterflies in Papua New Guinea and crocodiles in several Asian and African countries (183, 184). Others, for example some large African mammals, are managed in native habitats to provide revenues from tourism, hunting, and meat production for community-based projects (336). By providing income, these projects can lessen pressures to clear forests for planting of cash crops.

[47]Other efforts t. preserve tropical forests and biodiversity in general also will help protect sources of nontimber prOdUCtS. One initiative, for example, aims to develop conservation programs in collaboration with local organizations and national governments in 12 countries that contain an estimated 60 percent of the world's species and much of the remaining primary tropical forest (41; also see 159).

[48]Some investigators conclude that very little ''sustaimble' commercial harvesting actually occurs in tropical moist forests (39, **203).** Also see "Tropical Forestry Action Plan" below.

[49]The World Bank estimated that only 10 of the 33 countries that were net exporters of tropical forest products in 1985 would be net exporters by 2000 (215).

[50]Instead of establishing plantations, the company buys natural forest tracts or marginal farmland where the tree is found and hires local farmers as guardians (194, 228).

Table 7-3--FAO Estimates of Plantations Established by End of 1980 and During 1981-85 in 111 Developing Countries and Territories, by Region (number of countries in parentheses) (in millions of hectares)[a]

Region	Established by 1980	Established 1981-85	Total	Annual rate	Estimated percent of annual deforestation replaced with plantations
Tropical:					
Africa (42)	1.8	0.6	2.5	0.1	3%
Asia (15)	5.2	2.2	7.4	0.4	21%
C. & S. America (27)	4.6	2.7	7.3	0.5	9%
Oceania (6)	0.1	0.1	0.1	<0.1	34%
Total (90)	11.7	5.5	17.3	1.1	1 0%
Nontropical:					
Africa (7)	1.2	0.5	1.7	0.1	NE[b]
Asia (11)	14.5	0.3[c]	14.9	0.1[c]	NE
America (3)	1.6	0.6	2.2	0.1	NE
Total (21)	17.2	1.5	18.7	0.3	NE

[a]Based on official government responses to FAO survey; does not include trees planted on small landowner plots (e.g., agroforestry, windbreaks) or plantations of nontimber trees such as rubber, oil palm, coconut, and shade trees.
[b]NE = not estimated.
[c]Does not include value for China.

SOURCE: Food and Agriculture Organization, 1988.

suggests that clearcutting should not be allowed on a large scale unless acceptable management plans and stringent enforcement mechanisms are in place.

Another practice, ' 'natural' forest management, combines natural regeneration with small clearcuts to allow sustainable harvesting with little damage to remaining trees. Natural regeneration typically involves the growth of volunteer seedlings and saplings; for some species, a small ' 'gap' in the canopy is needed for seeds to germinate and grow initially. In one project in Peru, this gap is simulated by clearcutting long narrow strips from a mature forest, on a 30- to 40-year rotation (96, 97). Native trees regenerate naturally in the small, open strips. Oxen remove felled logs, and the timber is processed at a local cooperative run by villagers. In late 1989, the cooperative shipped its first exports to U.S. buyers (53).

Considerable research is needed on this and other practices. In general, though, the major problems associated with commercial logging are economic, political, and institutional. To ensure that logging in the tropics is conducted in accordance with accepted management norms, national governments and international organizations must develop rational management plans, enforcement mechanisms, and trading systems (see ' 'Options for Tropical Forests' below).

Managing New Forests

Reforestation

Reforestation consists of establishing forests on previously harvested lands, often in the form of monoculture plantations, sometimes in more heterogeneous stands; it can be of great use in improving watershed management and erosion control.

The potential for tropical reforestation varies widely. On degraded lands, barriers include competition with invading grasses that support periodic fires; hotter and drier microclimates in cleared areas; lack of appropriate seed sources; and poor soil characteristics (e.g., low nutrient and water-holding capacity, compaction from overgrazing) (188, 245). Reforestation is possible on degraded lands if proper techniques and ecologically suitable species are chosen (147, 149, 188), but it is likely to be difficult.

Many large reforestation projects involve establishing plantations on relatively less degraded land. As of 1985, about 17 million hectares of plantations had been established in tropical forest areas (see table 7-3).[51] Successful plantations have been established in countries as diverse as India, Malaysia, the Philippines, and Trinidad and Tobago (71, 235). However, the overall rate of establishing new plantations is relatively low—about 1 million hec-

[51]These data do not include trees planted around farm fields, as windbreaks, or along roadways (204).

[52]However, Palmberg (196) estimated higher rates for 1981 to 1985—2.9 million hectares per year of industrial timber plantations, 2.6 million hectares per year for nonindustrial purposes.

tares per year in the early 1980s, or one-tenth the estimated rate of deforestation (see table 7-3).[52]

Estimated growth rates for tropical plantations in the early 1980s ranged between 2 and 10 metric tons C per hectare per year (based on data in refs. 30, 71). OTA assumes that an average annual growth rate of 5 metric tons C per hectare might be maintained on plantations; this may be optimistic, given lower rates on degraded lands, problems associated with plantations, and a lower net effect when plantations replace previously forested land. How much land might be available is unclear.[53] If a program to double the current establishment rate were to begin in 1995, then carbon storage attributable to reforestation might amount to 50 million metric tons in 2000 (2 percent of 1989 emissions) and 200 million metric tons in 2015 (7 percent of 1989 emissions) (see table 7-2).

Problems with plantations include poor site and species selection, faulty management, fire, and disease (71). One of the largest projects, in Jari, Brazil, has been more expensive and less productive than anticipated (63), Some monoculture plantations in Southeast Asia have lost thousands of hectares due to pest infestations (204). Monoculture have other opportunity costs such as reduced biodiversity and less access to medicinal plants and other products.

Any reforestation effort must also contend with social issues such as land ownership and local needs. Reforestation projects could be designed to provide local people with products and services (e.g., medicines, food, etc.) from different forest successional stages, which would mean planting and managing more heterogeneous forests (26, 116, 316, 318) (also see 'Harvesting Nontimber Forest Products' above). Mixed-species forests might also reduce the likelihood and intensity of infestations (310),

Attempts also could be made to restore degraded lands to something resembling original conditions (84, 120), Although relatively little is known about how to do this, a pioneering effort to restore crop and range land back into dry tropical forest is taking place in northwest Costa Rica, on what will be over 70,000 hectares in Guanacaste National Park (158). It is designed to benefit local residents through watershed protection, employment, income from tourism, and educational programs (21 1). Another possibility is to restore damaged or cutover mangrove forests, which are important as sediment filters and as habitat for many marine species (258, 275). Several Southeast Asian countries (e.g., Malaysia, Vietnam) are attempting to restore mangroves and other coastal vegetation (243a, 258).

POLICY OPTIONS

This section describes policy options for influencing forestry management and land use practices in the United States and in tropical areas. Policy makers should recognize that the management practices described above might be affected by future climate changes, the impacts of which are difficult to predict for specific forest areas (see box 7-D).

Options for U.S. Forests

Policies to offset carbon emissions in the United States fall into three general categories: those encouraging increased carbon storage in existing wooded areas; those promoting biomass energy; and those for growing new trees in unforested rural areas and in urban communities. Several U.S. Department of Agriculture agencies, particularly the U.S. Forest Service (USFS) and the Agricultural Conservation and Stabilization Service (see box 7-E), could be instrumental in carrying out these policies.

Incentives for Increasing Carbon Storage in Forested Areas

Increasing carbon storage in forested areas as a means of offsetting CO_2 emissions actually means increasing the rate at which an entire forest ecosystem removes CO_2 from the atmosphere and stores it in wood, leaves, roots, soil and soil organisms, etc. While this carbon ultimately will be released back to the atmosphere (see box 7-A) unless it is permanently stored under conditions that do not allow decomposition, increasing total productivity still is an appropriate goal for the 25-year timeframe of this report. Most people are concerned with increasing the productivity of a forest's commercial *timber* component, because of possible capital returns from harvesting the timber. Whether an increase in timber

[53] Of formerly forested lands not currently used extensively for agriculture or settlement, Houghton (10S) concluded that 500 million hectares of mostly degraded land were available, including large areas of savanna in west Africa. In addition, he concluded that 365 million hectares of fallow areas could be reforested if shifting cultivation were replaced with permanent agriculture. Grainger (88) estimated that over 700 million hectares might be available for reforestation.

Box 7-D—Forests and Future Global Climate Change

The General Circulation Models (GCMs) currently used to make predictions about climate change have only limited regional resolution and cannot predict how individual trees might respond to local climate changes (see ch. 2). Nevertheless, they can be used to indicate, as a first approximation, how potential climate changes might affect forests.

First, changes in ***average*** temperature and moisture can affect the physiology and competitive regimes (i.e., with other plants), and hence survival and reproduction, of individual trees.[1] These effects could be positive or negative. For example, warmer conditions might enhance growth rates in boreal forests (16, 125) but decrease survivorship of some species' seedlings elsewhere (31, 35,79, 205).

Second, the frequency and intensity of ***episodic disturbances (e.g., fires,*** windstorms, pest and disease outbreaks) might increase in some areas, although they might decrease elsewhere. Little attention has been given to this issue, even though such events could hinder efforts to reduce deforestation or increase carbon storage. Where they occur, changes in episodic events may have greater effects on forest biomass and composition than would changes in average conditions (79, 117, 193). Changes in average conditions such as warmer winter temperatures also could allow some pathogens, parasites, and insects to expand into unaffected forests (79, '190), although currently affected forests might experience reductions in such problems.

Several reports summarize projections of how North American forests might respond to changes in average global climate (79, 117, 122, 136, 165,210,223, 294). The projections generally indicate that forests will not shift as units, but that some species would migrate to higher elevations (e.g., in the Northwest) and latitudes (e.g., in the East). For some species, however, shifts in suitable conditions may outpace natural dispersal rates (31, 261). Some areas, such as the southern part of the Southeast United States, might convert to scrub, savanna, or sparse forest. Shifts also could lead to competition with existing land uses (e.g., cropland).

Effects of these changes on CO_2 levels are difficult to predict. If existing forests suffer diebacks, then carbon emissions from decomposing trees could increase (223). Stressed trees that die also could increase fuel loads and hence fire intensity. On the other hand, overall productivity of Northeastern forests could increase if slow-growing spruces and firs are replaced by faster growing hardwoods.

Less is known about potential effects on tropical forests. Some consider it unlikely that higher temperatures will be directly detrimental (e.g., ref. 95). Warmer temperatures could even lead to boundary expansions, depending on factors such as changes in daily temperature regimes, how far polar air masses penetrate into the tropics, and cloud cover. However, increased seasonality of rainfall in humid tropical forests might greatly affect the fruiting of trees such as figs and palms that are important for humans and numerous birds and mammals (78).

CO_2 "Fertilization''—Laboratory and greenhouse experiments on crops and a few trees show that increases in CO_2 concentrations can result in CO_2 "fertilization" or "enhancement' '-increases in growth rates, efficiency of water and nitrogen use, and ability to withstand water stress (128, 136,222, 289).

This raises the **possibility** that increasing atmospheric concentrations of CO_2 might stimulate growth rates and associated carbon storage in natural forests. There is no evidence yet that this has happened, however, and debate about its likelihood continues (16, 125,238,289, 330). The experimental findings ca.nnmot be easily generalized. Virtually all the experiments have been short-term, conducted under conditions unlike those encountered by plants in natural conditions (13, 82,128,136, 190,330). In the field, plant growth may be limited by other factors (e.g., water, nutrients) that interact with plant physiology, by competition with other plants, and by pathogens.

Moreover, higher temperatures also might increase plant respiration rates, thereby increasing CO_2 emissions and partially or entirely offsetting carbon storage resulting from increased photosynthesis (109, 136,330, 331). Higher temperatures also could increase oxidation and emissions of soil carbon (125) and the production of methane in anaerobic environments (109).

[1] Changes also might occur in soil conditions and affect the microorg anisms that help make soils amenable for plants (323).

Box 7-E—USDA: Forest Service and Agricultural Stabilization and Conservation Service

U.S. Forest Service (USFS)-The USFS administers timber sales and other activities on national forest land, under the National Forest Management Act of 1976 and the Forest and Rangeland Renewable Resources Planning Act of 1974. It also administers programs to stimulate investments by private nonindustry landowners in forestry practices. Under the Cooperative Forest Assistance Act of 1978, the State and Private Forestry program provides assistance to State forestry organizations, which then offer direct assistance to landowners for pest and fire protection and forest management; this totaled $87 million in fiscal year 1989, including $2.5 million for urban forestry (306, 309). Under the Renewable Resources Extension Act of 1978, the agency provides assistance for forest management through extension service programs.

The International Forestry program assists international organizations such as the United Nations Food and Agriculture Organization and the World Bank in evaluating and implementing projects (309). One of its units, the Forestry Support Program, is managed with funding from A.I.D. and provides technical assistance to A. I.D., the Peace Corps, and NGOs (283). The USFS also operates two tropical forest research centers (in Puerto Rico and Hawaii) that conduct some research on agroforestry and reforestation (113, 278); the Forestry Private Enterprise Initiative, which helps small forest-based businesses (including ecotourism) in the tropics; and the Forest Products Laboratory, which conducts research on the use of temperate and tropical woods.

The USFS spent over $138 million on forest research in fiscal year 1989, including $14 million on global change. The proposed fiscal year 1991 budget for global change research is $23 million (306).[1]

Agricultural Stabilization and Conservation Service (ASCS)—The ASCS administers several programs with technical assistance from USFS, Soil Conservation Service, and State agencies (45). The **Forestry Incentives Program (FIP)** provides cost-sharing (up to 65 percent) for reforestation, timber management, and firebreaks, on private forest lands of less than 400 hectares. The **Agricultural Conservation Program** (ACP) provides cost-sharing to farmers for soil and water conservation practices, including tree planting and timber improvement. These programs treated over 140,000 hectares annually during the last few years, mostly (over 80 percent) for reforestation; in 1986, the FIP provided over $11 million, over 75 percent in the South, while the ACP provided over $6 million.

The ASCS also administers the **Conservation Reserve Program (CRP),** with assistance from the Soil Conservation Service and USFS. Established under the Food Security Act of 1985, the CRP is designed to improve soil, water, and wildlife resources by paying landowners to remove highly erodible land from production (284, 285) (also see ch. 8). Its goal is to have 16 to 18 million hectares enrolled by 1990, with one-eighth to be reforested. The Federal Government enters into 10-year contracts with farmers, makes rental payments, and pays one-half the costs of establishing protective vegetation. As of March 1990, about 0.9 million hectares were enrolled for tree planting (40 percent of the reforestation goal), over 90 percent in the South (45, 170a).

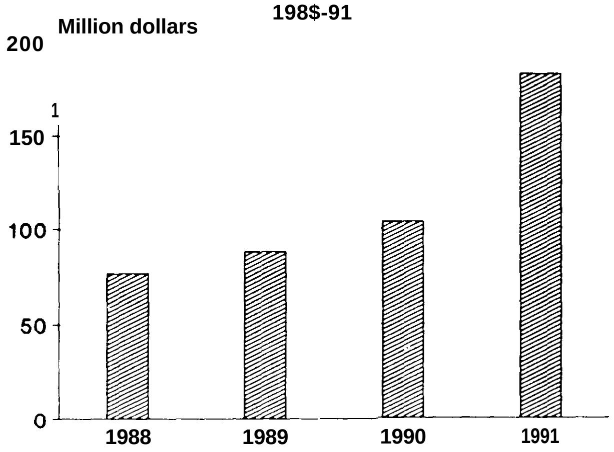
[1]The Forest/Atmosphere Interaction Priority Research Program is designed to research the effects Of climate change on forests and related ecosystems (298). It builds on the Forest Response Program, which conducted (through 1990) research on acidic deposition. The Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (Public Law 100-521) designated the USFS as the lead agency to continue research begun under the National Acid Precipitation Assessment Program and carried out by the Forest Response Program.

productivity represents a similar increase in total productivity, however, is an issue that requires esting. Assuming that it does, then incentives could be provided to increase timber productivity; incantives will differ for publicly and privately owned forests, but all should account for potential tradeoffs such as increased N_2O emissions from fertilization, increased erosion, or decreased biological diversity.

For public lands, Congress could direct the USFS and Bureau of Land Management to increase reforestation activities (including more stringent reforestation requirements in contracts with the private sector) and to consider using carbon storage as a criterion in forest planning processes (127).[54] To assess the extent to which ‘ ‘new forestry’ practices (see ‘Increasing Productivity’ can maintain higher

[54]Management objectives for National Forests, for example, are determined in accordance with provisions in the Forest and Rangeland Renewable Resources Planning Act and National Forest Management Act, within the overall framework set forth in the Multiple-Use and Sustained-Yield Act of 1960 (274).

Figure 7-5-Funding Levels for the U.S. Forest Servicers State and Private Forestry Programs, 198$-91



Levels for fiscal years 1988 and 1989 are actual spending; level for fiscal year 1990 is estimated spending; and level for fiscal year 1991 is appropriated funding. (All amounts are in real dollars.)

SOURCES: Office of Management and Budget, Executive Office of the President, *Budget of the United States Government, Fiscal Year 1991* (Washington, DC: U.S. Government Printing Off ice, 1990); U.S. Congress, "Continuing Appropriations for the Fiscal Year Ending September, 1988," Conference Report 100-498 (Washington, DC: Dec. 21, 1987); *Congressional Record,* 136(1 50): H-12409, Oct. 27, 1990.

levels of diversity and allow commodity production, Congress could direct the USFS to increase research on these practices in the National Forests.

For nonindustry private forests, Congress could continue to increase assistance to States and private landowners. In the Interior and Related Agencies Appropriations Bill for fiscal year 1991, for example, Congress increased funding for USFS State and private forestry programs (see box 7-E) from $104 million in 1990 to $183 million in fiscal year 1991, continuing the trend seen in the late 1980s (see figure 7-5). In addition, the 1990 Food Agriculture, Conservation, and Trade Act (Public Law 101-624) authorized a forestry stewardship program, in which the USFS would work with State and local governments, land grant universities, and the private sector to improve resource management on privately owned forest land. Congress could also consider increasing funding for programs administered by the Agricultural Conservation and Stabilization Service, such as the Forestry Incentives Program (FIP) and the Agricultural Conservation Program (ACP) (see box 7-E) (also see 111, 179). These programs currently reach only about 2 percent of nonindustry private owners, although as a group these owners are responsible for over 40 percent of all reforestation (see figure 7-4). The fiscal year 1991 appropriation for the Forestry Incentives Program was $12.5 million, the same as in fiscal year 1990.

For industry-owned timberland, investments might also be stimulated through changes in capital gains provisions. Congress could consider restoring preferential tax rates or providing a partial exclusion from taxable income, for timber held longer than 20 years, and allowing full annual deductions for expenses, as well as increasing funding for Federal assistance programs.[55] Analysts at the Natural Resources Defense Council (15) suggested that tax and program benefits be made available only to owners who comply with relevant forest management guidelines.

To increase Federal funding of assistance programs, one possibility is to use funds that would be saved if "below-cost" timber sales in national forests were eliminated.[56] Timber sales in general, along with USFS assistance in surveying and road construction, are used to promote the U.S. forest products industry.[57] For all 122 national forests, net revenues to the government from fiscal year 1989 sales amounted to $403 million (307). However, 66 forests exhibited net losses totaling $45 million.[58]

Some local job losses in the timber industry are likely if below-cost sales are eliminated. In addition, 25 percent of gross revenues from all Federal timber sales (including below-cost sales) are paid to States, to be distributed to counties for roads and schools,

[55] Tax provisions that have been favorable for forestry investments include: capital gains; annual expensing Of some costs; and a reforestation tax credit (15, 139,226, 301). The 1986 Tax Reform Act eliminated differential rates for long-term capital gains.

[56] Assuming that demand for wood remains the same, eliminating such sales would not effect carbon emissions because harvesting would shift elsewhere.

[57] Repetto and Pezzey (218) suggest ‘1 iminating, over time, all Federal appropriations for forest management, other than for protecting biodiversity and other nonmarketable services. They propose financing management expenses out of net receipts from forest operations, and establishing user fees based on market values for nontimber values (which could increase pressure for more roads and other forms of access into old-growth and wilderness areas).

[58] Timber harvested from such sales accounted for about one-fifth of the total harvest from national forests. The only western forest to ShOW a net monetary loss was the Chatham unit of Tongass National Forest in Alaska (270, 303, 307). GAO (270) provide-s slightly different estimates of net losses.

and some of this would be lost as well.[59] Some rural towns and timber operators would probably need training, development, m-relocation assistance. Banning exports of unprocessed logs also might offset some 'job losses (see box 7-C). Indeed, the current ban on exports of logs from Federal lands, previously enacted annually in the appropriations process, has now been made permanent.[60] Congress also could make cost-sharing assistance under the FIP and ACP available only to States that ban exports from private and State lands, Potential disadvantages of export bans (90) include countering free-trade policies (although Japanese trade policies discourage imports of processed wood products); adding to the U.S. trade deficit; and job losses among longshoremen (possibly offset by new sawmill jobs).

Incentives for Biomass Energy To offset CO_2 Emissions

The Department of Energy's research program on short-rotation woody crops could be increased[61] and focused to reduce uncertainties regarding long-term productivity and costs. Increasing taxes on fossil fuel use (see ch, 1) will make biomass fuels more competitive, although it also could increase pressures to cut trees for fuel wood on lands not dedicated to biomass crops.[62] Also, farmers wishing to invest in biomass crops may be limited by loss of base acreage in commodity support programs (see ch. 8) and by lack of revenues for the first 5 years or so; this suggests that changes in support programs or provision of subsidies may be needed to stimulate investments in biomass crops on current cropland. Chapter 3 discusses other options for increasing the use of biomass fuels in electric utilities; chapter 5 discusses biomass use in vehicles. All of these options assume that the infrastructure to support cultivation and use of such crops is in place.

Incentives for Growing New Trees

Afforestation can be promoted through programs such as the Conservation Reserve Program (CRP) and the proposed America the Beautiful program and through financial mechanisms such as tax incentives or credits. Any program must consider the financial and technical resources needed to maintain trees in a healthy state once planted, a factor that will be even more critical if climate changes occur (see box 7-D).

Congress could expand the CRP's tree-planting goals and its incentives for enrolling land for tree planting (e.g., greater share of reforestation costs, longer contracts).[63] A variation might be to encourage new shelterbelts, perhaps through tax credits or by conservation compliance requirements tied to price support programs (see ch. 8).[64]

The Food Agriculture, Conservation, and Trade Act of 1990 also authorized startup funds for a new America the Beautiful tree-planting program (initiated by President Bush), as well as funds for urban and community tree planting and maintenance. The Interior and Related Agencies Appropriations Bill for fiscal year 1991 did not contain funding for the America the Beautiful program, but it almost doubled funding for the USFS's State and private forestry programs, which include tree planting and management (figure 7-5). However, infrastructure for increased planting also may need to be developed, since current planting is near the historical peak of about 1.4 million hectares per year; funding for long-term maintenance also will be needed.

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59 The USFS budget request for fiscal year 1991 proposed phasing out below-cost sales on 12 forests, and testing whether increased funding for recreation would result in increased recreational usage to offset revenue losses to local economies caused by eliminating the sales. This proposal is opposed by many States with targeted forests because of fears about revenue losses (58).

60 The Customs and Trade Act of 1990 (Public Law 101-382) permanently bans exports of unprocessed logs from Federal lands in the West, bans exports of at least 75 percent of the annual sales volumes of unprocessed timber from State lands, and bars mills from 'substituting' unprocessed timber from public lands for exported unprocessed timber originating from private lands.

61 Federal support for research on energy from biomass and municipal waste dropped from $58 million in fiscal year 1981 to $13 million in fiscal year 1989 (187),

62 However, a tax on "carbon" per se could have the opposite effect because the carbon content of wood is about the same as that of coal.

63 In the Food Agriculture, Conservation, and Trade Act of 1990 (Public Law 101-624), Congress expanded CRP eligibility criteria to include, for example, marginal pasture lands previously converted to wetlands or wildlife habitat, marginal pasture lands to be converted to trees in or near riparian areas, and croplands that contribute to water quality degradation.

64 Options more readily implemented at the State and local levels include requiring developers to grow trees (onSite or elsewhere) or contribute to a reforestation fund if they clear a certain portion of trees on a development site; and giving property tax breaks to landowners that agree not to convert or degrade forest lands (e.g., as in North Dakota; see ref. 32).

Congress also could consider providing tax incentives (similar to ones for energy conservation) for planting and maintaining urban trees (especially near buildings, to save energy used for cooling).[65]

Options for Tropical Forests

Introduction

Policy makers must recognize that changes in tropical forests are driven by underlying factors such as national and multilateral economic development policies, foreign debt, lack of land tenure, and population growth.

Some governments favor development of tropical forest areas because of concerns about national security, population pressures, and foreign debt (17, 174, 215, 216, 235, 275, 340). Transmigration, highway and dam construction, and other projects undertaken in response to these concerns have greatly increased deforestation (10, 66,67, 153, 174, 216, 249). Many projects have been partially funded by multilateral development banks, which have only recently begun to consider long-term environmental costs in their decisions about projects. In addition, forest products are exported to obtain foreign exchange and service debts (225), but frequently at a pace that cannot be sustained for long periods.

Some agricultural policies have promoted converting forests into large cattle ranches, particularly in Latin America. In Brazil, for example, previous tax laws penalized owners of "unimproved" forest land but virtually exempted agriculture and ranching from taxation (17, 66). The government suspended most of these provisions (38), but ranches still are an attractive hedge against inflation (17, 98). Many countries also maintain low food prices to help urban populations, which lessens incentives for better agricultural practices.

Timber policies often enable forest industries to generate profits by rapidly depleting timber stocks (213, 214, 215, 216, 340). Such policies include short-term concessions (e.g., less than 30 years), tax holidays, low "rents," and negative interest rates. Industrialized nations, by erecting tariffs on processed tropical imports (to protect their own industries), encourage inefficient harvesting in tropical forests because full market values for the resources cannot be obtained.

Population growth exacerbates all of these factors. Populations in developing nations are expected to almost double to 7 billion by the year 2025 (see ch. 9). This growth, coupled with high poverty rates and inequitable land distribution, increases pressures to clear forests for agriculture. In many developing countries, most arable land is owned by a small upper class or by middle-class land speculators (98, 173, 275). Without access and tenure to productive farmland or access to alternative livelihoods, subsistence farmers often migrate into forest frontiers (98, 101, 275).

Given this background, potential U.S. policies to influence what happens in tropical forests can be geared to:

- encourage continued change in multilateral development bank policies;
- address population planning, land reform, and debt reduction;
- build host country institutions and increase research;
- provide assistance for nontimber alternatives; and
- promote improved commercial forest management.

A number of U.S. and international agencies and programs could be instrumental in pursuing such policies (see boxes 7-E and 7-F). The United States also could support development of an international forestry convention or protocol that sets global standards for conserving and managing forest resources, perhaps within the context of a global climate change convention.[66]

Encourage Continued Change in Multilateral Development Bank Policies

The International Development and Finance Act of 1989 (Public Law 101-240) directed the U.S. Executive Directors of each Multilateral Development Bank (MDB) (see box 7-F) not to vote in favor of proposed actions that would have significant

[65] The American Forestry Association has launched a 'Global Releaf' project, the objective of which is to plant 100 million young trees (larger than seedlings) around U.S. homes and buildings by 1992 (166, 167, 230); this would increase the number of trees in urban areas by an estimated 15 to 20 percent.

[66] As recommended by the FAO (76, 77), IPCC (114, 114a), and Ullsten et al. (264), which differ somewhat, however, on the potential relationship between a forestry convention and a climate change convention.

Box 7-F—Multilateral and Bilateral Institutions and Programs

Multilateral development banks (MDBs) include the World Bank and its affiliate, the International Development Association, and the Inter-American, Asian, and African Development Banks. World Bank lending for forestry-related projects is expected to be about $1 billion by 1992 (334). Many MDB projects have led directly or indirectly to deforestation, but recently the banks have begun to address these issues. U.S. Executive Directors to the MDBs are directed through the Department of Treasury's Office of Multilateral Development Banks (275).

International assistance agencies such as the United Nations Development Program (UNDP), Food and Agriculture Organization (FAO), UN Environment Program (UNEP), and more regional agencies (e.g., Commission of European Communities) provide funding for tropical forestry. The FAO is the largest organization addressing forestry; it inventories forest resources, conducts research on forest management practices, and coordinates the Tropical Forestry Action Plan. Even so, less than 5 percent of FAO's budget is allocated to forestry (264).

The Tropical Forestry **Action Plan (TFAP)** was initiated in 1986 under the sponsorship of the World Bank, UNDP, FAO, and World Resources Institute to provide a framework for enhancing donor cooperation and funding in: integrating forestry into improved land use practices, improving forest-based industries, restoring fuelwood supplies, conserving forest ecosystems, and building developing country institutions (73, 89, 142, 328, 340). Coordinated by FAO, the TFAP initially involves a review of the forestry sector in requesting countries; to date, over 50 countries have requested reviews. A nationa1 forestry action plan then is prepared that identifies potential projects amenable to financing from donors. TFAP's implementation, however, has been severely criticized (see "Options for Tropical Forests").

The International Tropical Timber Organization (ITTO) was established under the International Tropical Timber Agreement (265), which came into force in 1985. Its goal is to provide a framework for coordination and cooperation between tropical timber producing and consuming countries regarding tropical timber economies. Operational since 1987, it has 43 member countries representing 95 percent of world tropical timber trade and over 75 percent of remaining tropical rain forests. It uses voluntary member contributions to support projects for improved forest management and reforestation, increased domestic processing, market analyses, and better pricing structures. Japan has been the largest supporter among industrialized nations that have made voluntary contributions.

The **U.S. Agency for International Development (A.I.D.)** provides bilateral support for agroforestry, natural forest management, and reforestation projects through its own programs, the USPS Forestry Support Program (see box 7-E), the ITTO and TFAP, and international research organizations. It spent $72 million in fiscal year 1989 on about 160 tropical forest projects in 40 countries. It also provides support through the Food for Peace program, for example by distributing food to villagers engaged in forestry activities (267), and through projects for distributing more efficient cookstoves (268). The Foreign Assistance Act (amended by Public Law 99-529) requires A.I.D. to conduct environmental assessments for projects that significantly affect natural resources in developing countries, places priority on conservation and sustainable management of tropical forests and on practices such as agroforestry, and requires that NGOs be used to manage relevant projects when feasible. A.I.D. has had environmental review procedures for its projects since 1978; its Early Project Notification System requests information (submitted to Congress semi-annually) from field missions and embassies, NGOs, and MDBs about potential environmental problems associated with upcoming MDB loans (31 1).

environmental effects, unless an environmental impact assessment of the action and its alternatives had been conducted. The World Bank (332, 333), for example, recently outlined procedures for assessing the environmental consequences of its proposed projects. This is a critical step, but it is too early to ascertain its effect.[67] Bank procedures also do not provide for cross-compliance among different loans to a country.

Congress could continue to review MDB progress in implementing environmental impact assessment procedures, particularly to learn how these proce-

[67]For example, some observers question whether sufficient staff will be hired or whether the public will have substantive input in decisionmaking (3, 20, 101, 262). Nor is it clear how to account for previous projects that lead to new ones with environmental consequences (e.g., Brazil's pig-iron smelter project will use railways and mines built with previous Bank funding).

dures actually affect tropical forests.[68] It also could direct the U.S. Executive Directors to promote cross-compliance, so that even when all funds from a loan have been distributed to the recipient country, noncompliance with its environmental provisions would result in loss of funds from other loans. In addition, it can continue encouraging MDBs to:

- make loans contingent on changes in host country policies (e.g., elimination of subsidies for ranching and poor logging);
- increase loan provisions designed to strengthen environmental ministries, extension services, and monitoring capabilities of developing countries; and
- increase involvement and capabilities of local non-governmental organizations (NGOs) and communities in planning and implementing projects.

Address Population Growth, Land Tenure, Foreign Debt

Support Population Planning and Land Reform—The United States could increase its assistance through the Agency for International Development (A. I.D.) for family planning services in developing countries and for international organizations such as the U.N. Fund for Population Activities and the International Planned Parenthood Federation. This critical issue is discussed in chapter 9, The United States also could support both agrarian land reforms initiated by developing countries (especially those focused on large, unproductive landholdings in regions where small farmers are leaving due to mechanization and other factors) and urban projects that increase employment opportunities for rural migrants.

Debt Reduction and Debt-for-Nature Swaps—One option to reduce foreign debts and promote natural resources conservation is ‘‘debt-for-nature swaps.’ Private, nonprofit groups can purchase debt sold by commercial banks at discounted rates in the secondary debt market, and then exchange or ‘‘swap’ the debt note with a developing country for an obligation by that government to create some type of conservation program. As of 1989, Bolivia, Ecuador, Costa Rica, Madagascar, and the Philippines had participated in such swaps, with a reduction in external debt of $100 million (340).

Although only 1 percent of developing country debt is traded on the secondary market, reorienting even a small percentage of current debts to natural resource conservation and management is helpful, especially given the lack of funds generally available for such purposes in many developing countries (141, 212, 320).[69] Congress could direct the Internal Revenue Service to publicize a 1987 ruling (and clarifications) that allows creditors, including U.S. banks, to receive full-value tax deductions when part of a debt is donated to eligible NGOs for use in the debtor country (293).[70] Congress also could continue trying to have MDBs evaluate ways to facilitate swaps.[71]

Provide Assistance for Institutions and Research

Environmental Ministries and NGOs—Few developing countries have adequate programs for forestry management or agroforestry (84, 329). Congress could direct A.I.D. to devote more resources to improving the abilities of environmental ministries and extension services to collect data and analyze environmental effects, monitor forest practices, improve planning, and enforce regulations. Congress also could increase direct funding and technical support through A.I.D. for U.S. and foreign NGOs that work on forestry-related issues.[72] These groups often can quickly implement small-scale, innovative projects; for example, CARE (Cooperative for American Relief Everywhere) and the Pan

[68] In a related vein, the United States could promote revision of the U.N. ’S accounting system fOr national economic performan ce, which places little value on forest services such as watershed protection and nontimber products (92, 152, 215, 216, 217) (see ch. 9).

[69] Swaps have been criticized, though, for refocusing domestic priorities away from infrastructure, housing, and food supplies and for ‘giving’ awaY resources, and in some cases for ignoring the needs and rights of tribal people living in affected areas. However, the debtor country retains ownership of the resources in question and can decide for itself whether a proposed swap is worthwhile (141, 195).

[70] To date, larger banks have not found trading debt at discounted rates attractive. Most swaps have involved the purchase of secondary debt by NGOs, using funds from foundations and individual donors (341). As of 1988, onfy one bank had made a debt donation, to the amount of $250,000 (340).

[71] Currently, MDB loans cannot& used for swaps because they are not salable on secondary markets and cannot be rescheduled (269, 293). In 1987, Congress instructed the Department of Treasury to analyze potential ways in which MDBs could facilitate swaps. The 1989 International Development and Finance Act directed the U.S. Executive Directors to promote protection of sensitive ecosystems through swaps.

[72] The 1989 International Development and Finance Act also requires the. U.S. Executive Directors to MDBs to promote increased assistance and support for non-U. S. NGOs.

American Development Foundation have been instrumental in agroforestry projects (89, 275, 335).

International Research Organizations-Congress could increase support for international research organizations that address forestry-related issues, such as the International Council for Research in Agroforestry and the Consultative Group on International Agricultural Research (CGIAR).[73] No central body, however, coordinates tropical forestry research or offers help to donors and national governments (1 19, 221, 252). The United States could support development of an applied research system that both focuses on issues not currently covered adequately (e.g., nontimber forest products, natural forest management) and coordinates existing efforts. Congress also could increase support for U.S. university and Peace Corps programs to train U.S. professionals in tropical forestry (54, 164, 266) and direct A.I.D. to expand its support of research and training in forestry.

Provide Assistance for Nontimber Alternatives

Direct A.I.D. funding for tropical forestry projects was $72 million in 1989 (see box 7-F), about 1 percent of total A.I.D. economic assistance. Congress could increase funding for A.I.D. projects on agroforestry, sustainable agriculture, and nontimber forest products (without reducing other programs). Congress also could ensure that A.I.D. systematically assesses the potential for its projects to decrease deforestation.[74] USFS tropical research centers and the Forest Products Laboratory (see box 7-E) could be expanded to include more research and training on nontimber forest products.

Internationally, the United States could promote alternative land use practices through its influence on MDB policies, and it could promote sustainable harvesting of nontimber products through its potential influence on the International Tropical Timber Organization (ITTO) and Tropical Forestry Action Plan (TFAP) (see next section).

Promote Improved Commercial Forest Management

Where commercial timber harvesting occurs, existing incentives for short-term use and mismanagement need to be replaced with incentives for better practices (1 14a), For example, the United States can work through international organizations and programs to promote:

- longer terms for timber concession licenses;
- increased ability of government ministries to oversee harvesting;
- increased research on natural forest management;
- more plantations and agroforestry on degraded lands; and
- importing forest products only from areas managed on a sustainable basis.

Some of this can be done through the MDBs and UN agencies such as the FAO. Congress also could direct U.S. agencies such as A.I.D. and USFS to expand activities in these areas, as well as to work together more often (e.g., as they did in Honduras on a project contracted by USFS and funded by A.I.D. in 1989).[75]

It may be even more important for the United States to help make the TFAP and ITTO more effective vehicles for promoting forest conservation and improved commercial forest management (114a).

Tropical Forestry Action Plan—The TFAP was designed to improve forestry practices in developing countries through cooperative efforts between donors and host countries (see box 7-F). However, its implementation has been criticized for stressing export-oriented commercial forestry instead of conservation; failing to address issues such as land tenure; perpetuating "top-down" planning; and failing to develop the capabilities of host countries (3, 36, 39, 101, 146, 224, 234, 259, 262). Some groups oppose increased lending by MDBs for

73 For descriptions, see refs. 42,89, 151, 275; but also see criticisms in ref. 244. CGIAR recently expanded its mandate, to address tropic&d deforestation through research on sustainable agriculture (42).

74 Public Law 101.167 and A.I.D. regulations require the agency to issue guidance to its missions and bureaus on the need to reduce greenhouse gas emissions associated with its projects, and to identify key developing countries in which forest conservation along with energy efficiency and renewable energy, could significantly reduce emissions.

75 The USFS historically has had no direct mandate for its international programs. Congress could provide such authority, as well as provide stable funding to the Forestry Support Program to directly serve NGOs and additional funding to the Forest Products Laboratory to develop new products (including nontimber ones) from tropical resources and to transfer technologies to developing countries. The United States also could demonstrate leadership by increasing research on reforestation of degraded tropical forest lands on its insular territories (278), through the USFS tropical forest research centers (see box 7-E).

commercial logging projects until these issues are resolved.

Two recent reviews, commissioned by the FAO and the World Resources Institute (both original cosponsors), confirmed many of these problems and also noted that project quality control, public access to information, and criteria for monitoring performance at the national and international levels are lacking (264, 328). While the United States could withdraw its support for and participation in the TFAP, it probably is the only international vehicle that could address these problems in a comprehensive manner.

The reviews recommended that TFAP be substantially restructured and redirected.[76] Congress could ask A. I.D., EPA, USFS, and the State and Treasury Departments to assess progress in reforming TFAP. Assuming the major problems are being resolved, Congress could direct the agencies to increase support for the new TFAP.[77] This support can, for example, include increased training for host institutions and NGOs, technical! assistance in assessing needed policy reforms, and financial assistance in carrying out new national Forestry Action Plans.

International Tropical Timber Organization (ITTO) and Trade--Some people have called for banning imports of tropical timber products in order to reduce harvesting of tropical forests. Indiscriminate bans, however, might remove the few existing incentives for improved management of those forests, which will continue to be cut for domestic purposes and for foreign markets that do not impose bans.

Alternatively, and along with improving the TFAP, the United States could work through the ITTO to link trade in tropical timber products with improved forest management. The United States could support ITTO efforts to have timber-producing countries adopt and implement guidelines on sustainable forest management (1 18). It also could support ITTO and other projects that explore pricing reforms within host countries (e.g., increased rents or fees from timber companies for the resources they harvest) and labeling mechanisms in international trade. If labeling mechanisms could be developed internationally, then imports (including nontimber products) might be allowed only from areas managed according to internationally acceptable forest management practices and labeled as such. Improvements in internal pricing policies, labeling mechanisms, and international guidelines for acceptable forest management could be incorporated into new national Forestry Action Plans developed under a revised TFAP. Moreover, ITTO and a revised TFAP also might encourage harvesting only in secondary forests, or at least reducing harvests of low-value products in primary tropical forests. U.S. influence in the ITTO currently is undermined, however, because it is in arrears of dues (slightly over $200,000). Congress could authorize payment of dues and additional funding for financing ITTO projects.[78]

The United States and other developed countries also could use ITTO and other forums to discuss, with producer countries, lowering the high tariffs that developed countries impose on imports of processed tropical wood products. These tariffs are enacted primarily to protect domestic processing industries, but they lead to increased imports of unprocessed tropical logs and reduce incentives for better harvesting in tropical forests.[79] Reducing them would allow developing countries to obtain the full market value for their resources, which might stimulate development of more efficient processing industries in these countries and allow them to compete in world markets without subsidies from their own governments (84, 204,215, 216).

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[76] In particular, t. 1) change from a project. specific, donor-driven plan to a systematic, host-driven program, with a new international management structure; 2) focus more on people who live in or use forests, forest degradation and conservation and sustainable economic use (including land use in surrounding areas); 3) increase institutional capacities of host countries; 4) stimulate policy reforms in host countries (e.g., tax policies, timber concessions) and in development assistance institutions (e.g., criteria for funding projects); and 5) revise guidelines to delineate responsibilities of donors and host countries and to lay out criteria on preparation of national plans, monitoring of and reporting on plan implementation, and other issues.

[77] The fiscal year 1991 budget requested $0.5 million for the TFAP Trust Fund (312).

[78] Congress appropriated payment of full dues in fiscal year 1990, but not payment of arrears. The proposed fiscal year 1991 budget requests full dues for fiscal year 1991, plus funds for some arrearages and $1 million for ITTO special projects (36a ,312).

[79] Several tropical countries, including Indonesia and peninsular Malaysia, have banned exports of unprocessed logs and tried to promote export of processed products (143).

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