Chapter 3

Status of Tropical Forests

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HIGHLIGHTS

- The area planted with trees in tropical regions each year is only about one-tenth of the forest area cleared.
- Gradual resource degradation, especially in the drier open forest areas, may have a greater long-term impact on human welfare than deforestation.
- Landsat imagery has greatly improved knowledge of closed tropical forests and this is enhancing forest management. However, data on open forests and forest resource degradation are still imprecise.
- Forest data aggregated by region may suggest that no global problem exists. However, country-by-country analyses show that rates of deforestation are high and forest area per capita is already low in many tropical nations.
- The acreage within tropical forests that is fallowed or abandoned is growing rapidly. Some of this will naturally return to forest cover, but most of it does not regain productivity without a concerted reforestation effort.
- Most tropical forest is owned by national or State governments, but locally recognized rights to use the resources greatly complicate management efforts.
- Tropical forestry historically has tended to neglect the basic needs of people who live in and near the forests. This is changing as laws, policies, and forestry professionals' attitudes give more attention to fuelwood, and to relationships between forestry and agriculture.

THE DATA BASE

Data on the extent and condition of tropical forest areas are abundant but widely scattered and frequently inaccurate. Some of this information is based on old, imprecise measurements or estimates that have been updated through simple extrapolation. Accuracy is further impaired by lack of standard definitions and classifications of forest types; thus, the data are difficult to compare across studies. Micro-level studies of project areas or watersheds contain some of the most reliable and detailed information on forest resources and land use, yet this information is hard to obtain because it is poorly distributed,

A comprehensive synthesis of data about the world's tropical forest resources was conducted by the United Nations Food and Agriculture Organization (FAO) with the assistance of the United Nations Environment Programme (UNEP) (3,4). The FAO/UNEP study is the first where the definitions of forest types and conditions are consistent across countries. It covers 76 nations; 73 nations are tropical or partly tropical, and 3 nations are outside the Tropics but are directly influenced by tropical monsoons. It does not include the tropical regions of China, Australia, islands off the coasts of Africa, the Pacific islands, or Puerto Rico. Some of the forests included are in places where the climate is more temperate than tropical.

The FAO/UNEP study relies mainly on data supplied by governments. Most measurements and estimates in various categories of forest were made in the 1970's. Then, using the estimated rates of change from one category to another, the figures were projected to represent the situation in each nation as of 1980.

Several nations did not have complete data, and for 13 of these FAO commissioned new Landsat analyses. Some of the government estimates used by FAO are also based on Landsat data.

Data gathered from the U.S. Landsat program has greatly enhanced the accuracy of information on the extent of forests. By using computers to study Landsat data, investigators can distinguish primary forests from secondary forests, closed forests from open forests and grasslands, and dominant types of trees (e.g., broadleaved, coniferous, mangroves).

Unfortunately, Landsat data have not been collected long enough to reveal trends in the forest cover over time. Hence, only a few of the estimated deforestation rates given in the FAO/UNEP study, presented later in this chapter, are based on remote sensing data. The rest are mainly subjective estimates. In addition, since expertise and computers to analyze Landsat data are not available in some tropical nations, many analyses have relied on visual interpretation of images, This method is more subjective and less sensitive to small-scale changes in forest area boundaries. In some cases, images cannot be used because of cloud cover,

EXTENT OF REMAINING TROPICAL FOREST

Closed Forest

Tropical nations contained some 1.2 billion hectares [ha) of closed forest at the end of 1980, Tropical America has 57 percent of the world's closed tropical forests, while Asia has 25 percent, and Africa has 18 percent (fig. 13). These forests are unevenly distributed among the tropical nations, Brazil alone has nearly two-fifths of the world's total closed tropical forests and Indonesia and Zaire each account for nearly another tenth (table A-1 in app. A).

The condition of closed tropical forests may be divided into several categories: undisturbed, logged, managed, physically unproductive, and protected areas. Table A-2 in appendix A shows the percent of forest in each category for each of the 76 nations.

Over half (56 percent) of the total tropical closed forest is classified as undisturbed forest. This forest has commercial potential, but most of it is relatively inaccessible to human populations. When Brazil and Zaire with their enormous remote forests are excluded, the remaining tropical nations have two-fifths (41 percent) of their closed forest in the undisturbed category.

Another 14 percent of the total closed forest is productive forest that has been logged but is not under active forestry management. Ivory Coast, Togo, Benin, Sri Lanka, and Belize all have at least *60* percent of their closed forest in this condition. Some other countries have had extensive logging but register little forest in the logged condition because farmers quickly convert the logged forest to temporary or permanent cropland. A prime example is Thailand, which has had extensive logging but shows no forest in the logged condition.

Only about 3 percent of the total closed tropical forest is classified as managed. Much of this is in logged-over condition, but significant investments are being made to manage natural regeneration. India classifies 63 percent of its closed forest as managed; Burma and Malaysia each classify about 12 percent as managed. Excluding these three countries, only **0.3** percent of the rest of the tropical closed forest is classified as managed. Most of that is in Ghana, Uganda, Kenya, Sudan, and Zambia.

Another one-quarter (23 percent) of the closed forest is unproductive for physical reasons. Much of this has not been disturbed

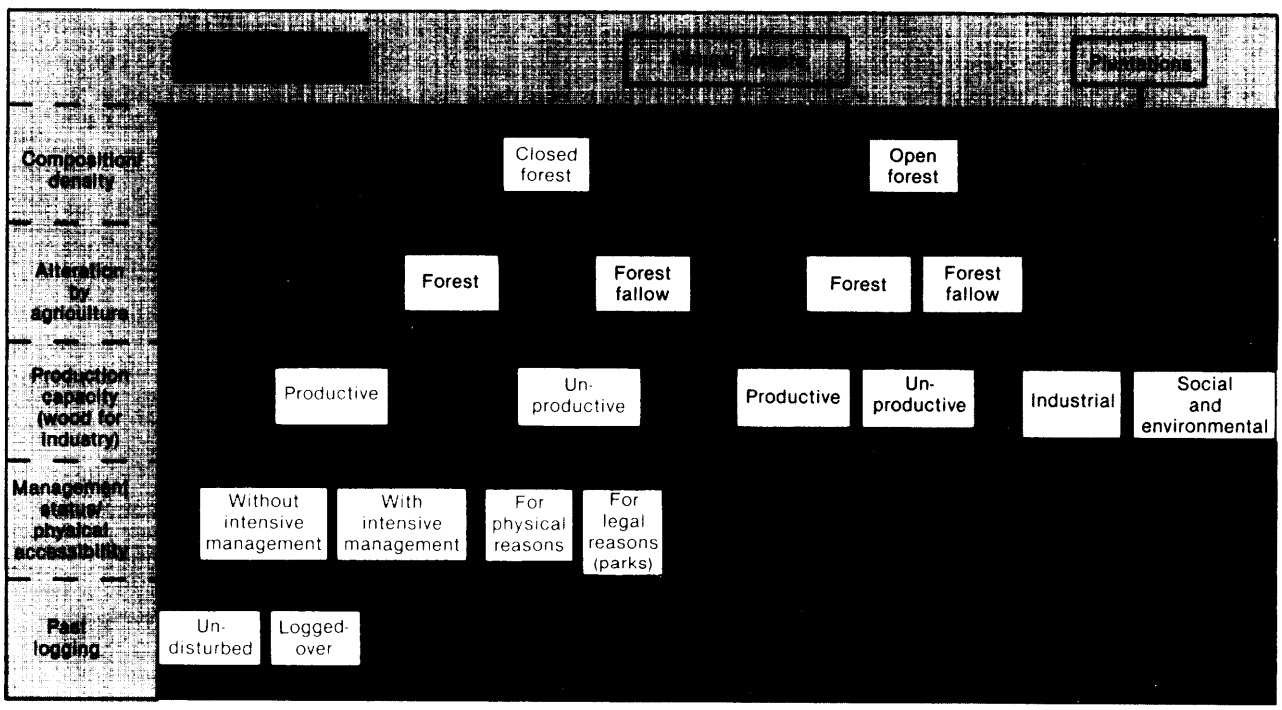
Definitions of Forest Categories

To dicuss; the status of the world's tropical fores? resources, the FAO/UNEP study divides forests into a number of categories (fig. 12). Those used in this report are:

- Closed forest includes land where trees shade so much of the ground that a continuous layer of grass cannot grow. The tree covrer is often multi-storied. Trees may be evergreen, semi-deciduous, or deciduous. Closed forests grow where the climate is relatively moist. The data on closed forest areas do *not include the land which is forest fallow.* which is accounted for separately. Forest plantations are also separate,
- Broadleaf forest is a subset of closed forest, where broadleaf species (dicotyledons or monocotyriedons] predominate. The broadleaf trees (especially the dicotyledons) are often referred to as "hardwoods." The FAO/UNEP study makes a separate category for bamboo-dominated forests, but these are ioncluded with the broadleaf forests in this report.
- Conifer forest is another subset of closed forest. It includes only areas where conifer species (gymnosperms) predominate. These trees are often referred to **as "softwoods. "**
- Open forest has trees that cover at least 10 percent of the ground but still allow enough light to reach the forest flour so that a dense, continuous cover of grass can grow. The grass cover ill creases the likelihood of grazing by livestock and the spread of fires. open forests .generally occur where the climate is relatively dry. The data on open forest areas do include the *land which is forest fallow.* For tropical Africa, data are also available to separate the open forest fallow from the total open forest.
- Productive forest is a term used to describe subsets of both closed and open forests. In productive forest, the characteristics of the trees, terrain, and forest regulations potenilly allow the productiun of wood for industrial purposes (e. g., sawlogs, veneerlogs, pulpwood, and industrial poles). The distance to consumption or export centers is not taken into account, so the category includes some forests that are not now economically accessible.
- Undisturbed forest is productive forest that has not been logged or cleared in the last 60 to 80 years. The category includes both primary forests and old growth secondary forests. It is not applied to open forests because nearly all open forests have been subject to cutting, burning, and grazing.
- Logged-over forest is productive forest area that has been logged or cleared at least once in the last 60 to 80 years but does not fit the criteria for managed forest. This is category is not appllied to open forests.
- Managed forest is productive forest wher harvesting regulations are enforced, silvicultural treatments are carried out, and trees are protected from fires and diseases.
- Unproductive forest for physical reasons is not suitable for industrial wood production due to rough or inundated terrain or poor growth characteristics of the trees (stunted or crooked).
- Legally protected forest is the category for forest where logging is prohibited by law. It includes a variety of parks and protected areas. Illegal logging does occur in some of these areas.
- Forest fallow is land that has been cleared for cultivation and subsequently abandoned so that it may again have some woody vegetation. This category. also includes patches of land t hat are being used to grow crops and some patches where forest has not been cleared but are too small to account for separately. The category is not supposed to include land where erosion or leaching have so degraded the site that only shrubs or grasses grow after the land is abandoned. Land in the forest forest fallow category is excluded from the definition of closed forest but included in the definition of open forest,
- Plantations are tree stands that have been established by human activity. The term includes reforestation (reestablishment of a tree cover on deforested or degraded forest lands) and replacement of natural forest by a different tree crop.
- Industrial plantations are sites wherc trees are planted to produce sawlogs, veneer logs, pulpwood and pitprops. This category excludes plantation that produce fuelwood forindusttrial use.

- Social and environmental plantations are designed for soil and water protection or to produce fuelwood and charcoal, polewood or construction wood for local use, or nonwood products, such as gum arabics. The category excludes plantations for nonwood commodities such as rubber, palm oil, coconuts, cloves, coffee, and cocoa. It also excludes trees planted to shade agricultural crops.
- Shrubland has woody vegetation covering at least 10 percent of the ground, but the main woody plants are bushy species with a height at maturity of 0.5 to 7 meters. Shrubland may be the natural vegetation under dry or otherwise stressful conditions, or it may result from severe degradation of open or closed forest land. The data on shrubland areas include some fallow agricultural land.

Figure 12.—Classification of Woody Vegetation

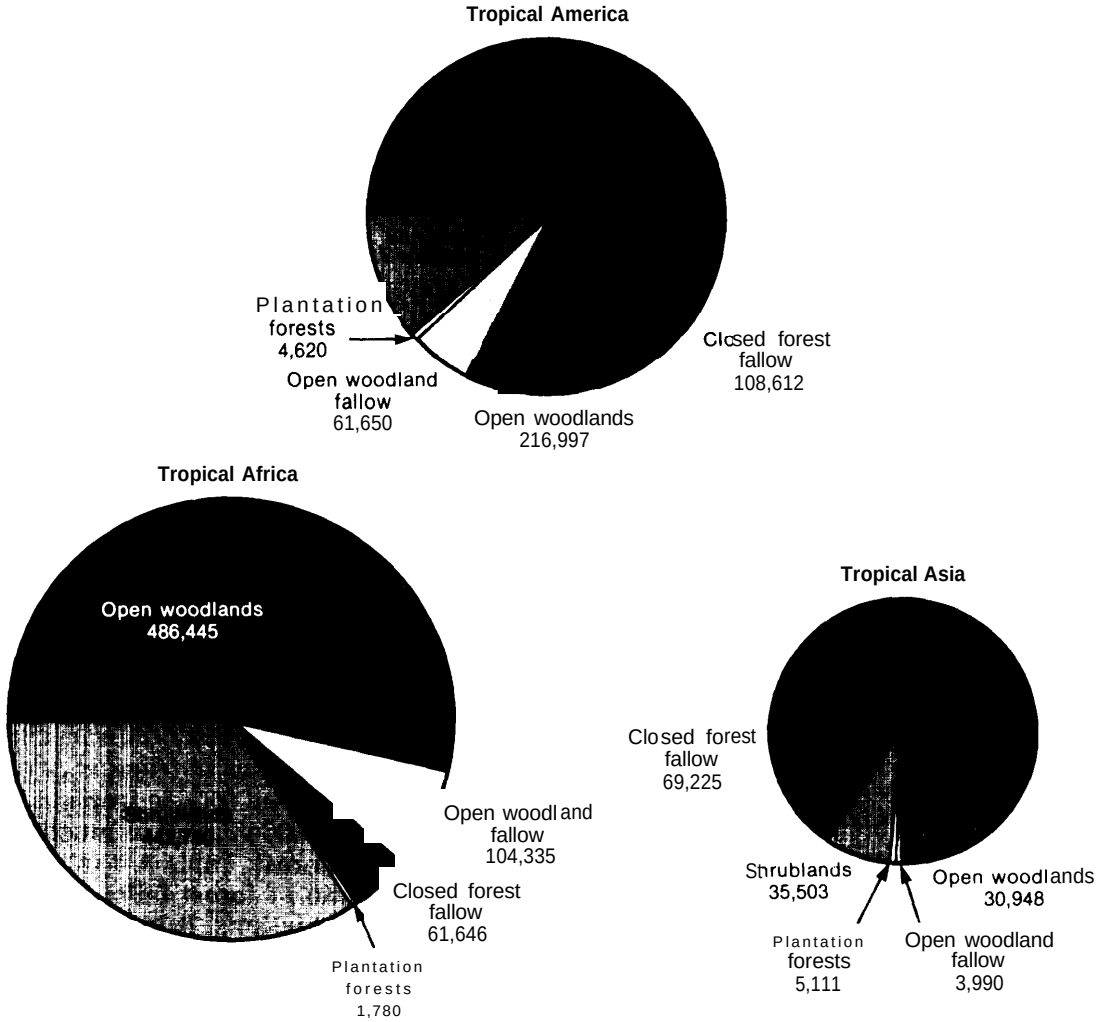


SOURCE: Adapted from Food and Agriculture Organization/United Nations Environment Programme, *Tropical Forest Resources*, Forestry Paper No. 30 (Rome: FAO, 1982)

by cutting; it is either too steep or too wet for logging or farming, However, this category also includes forest where the trees have no potential for industrial wood production, in some cases due to excessive cutting and consequent resource degradation, Brazil, Indonesia, Peru, Mexico, New Guinea, and Zaire each have at least 20 million ha of forest unproductive for physical reasons. The name of this category is misleading, since much of' this forest can be productive for fuelwood and other nonindustrial products and for essential environmental services such as watershed protection,

Finally, about 3 percent of the closed tropical forest has been given park or other legal protection status. Again, the percentage of the total hides an unequal distribution. Over half

Figure 13.—Areas of **Woody Vegetation**[a] **in** 76 Tropical Nations by Region
(thousands of hectares, **1980 estimates)**



[a]*Closed forest* has dense canopies and no continuous grass cover. *Open forest* has scattered trees and continuous grass cover. *Forest fallow* is land used or abandoned from agriculture. *Shrubland* has wood vegetation under 7 meters tall.

SOURCE: Adapted from Food and Agriculture Organization/United Nations Environment Programme, *Tropical Forest Resources* Forestry Paper No. 30 (Rome FAO, 1982).

(55 percent) of the protected forests are located in just four countries—India, Zaire, Indonesia, and Brazil. Despite the legal status of park lands on paper, many of these forests in fact do not receive much protection (3).

Open Forest and Shrublands

Tropical nations contain some 746 million ha of open forest and 624 million ha of shrubland. Whether the natural vegetation of a tropical area is closed forest, open forest, shrubland, grassland, or desert primarily depends on how dry the climate is and on the moisture-holding capacity of the soil. To an increasing extent, however, it also depends on human-caused factors (11).

Generally, closed forests grow where average annual rainfall is above 1,600 millimeters (mm). Open forests are found where rain is from **900** to l,200 mm. In areas with 1,200 to 1,600 mm of rain, the natural cover may be either open or closed forest, depending on fire history, soil, frequency of drought, and other environmen-

tal factors. Shrublands grow where rain is below 900 mm. In transitional areas, fires and livestock grazing can convert closed forest to open forest and open forest to shrubland. Conversely, closed or open forests can be reestablished in some places when fire and other pressures are eliminated (4,11).

Open forest and shrubland areas are unevenly distributed among tropical nations. The data describing these types of forests are much less accurate than for closed forests. This is partly because boundaries between open forest, shrubland, grassland, and fallow agricultural land are difficult to determine. It is also because there has been less interest in measuring or monitoring open forests and shrubland. Table A-3 in appendix A shows estimates for areas of open forest and shrubland in each of the 76 nations. Together, the African nations have most (65 percent) of the tropical open forests, but Brazil again dominates with 157 million ha. Zaire has 71 million ha; Angola has 51 million ha.

Shrublands also are mainly (7 I percent) found in Africa. Sudan has 87 million ha of shrubland, and other African nations with large expanses of shrubland include Tanzania, Central African Republic, Zambia, and Ethiopia. In tropical America, Brazil has 61 million ha; Paraguay, Bolivia, and Mexico also have extensive shrublands. Among the tropical Asian nations, Thailand, Kampuchea, Laos, and Indonesia all have substantial shrubland areas.

Since open tropical forests are more easily penetrable than closed forests, nearly all of them have been cut, burned, or grazed by livestock. Hence, no open forests are classified as undisturbed. Two-thirds of tropical America's open forest is classified as productive—having potential to produce wood for industry, In Africa, where these forests are generally drier, only one-third is classified as productive; just over one-fourth is classified productive in tropical Asia.

Although few open forests fit the FAO/UNEP definition for "productive," these woodlands are important for nonindustrial products and services. Much, perhaps most, of the open forest is used for livestock grazing and fuelwood collecting. These forests protect soils and watersheds in the semiarid regions and their wildlife is important as food. Further, many of the trees are legumes capable of converting atmospheric nitrogen to fertilizer, and so they are important for restoring the fertility of abandoned croplands.

Parks and protected areas account for 9 percent of the African tropical nations' open forests. Tropical America has given protected area status to just 1 percent, and tropical Asia has designated 2 percent for protection.

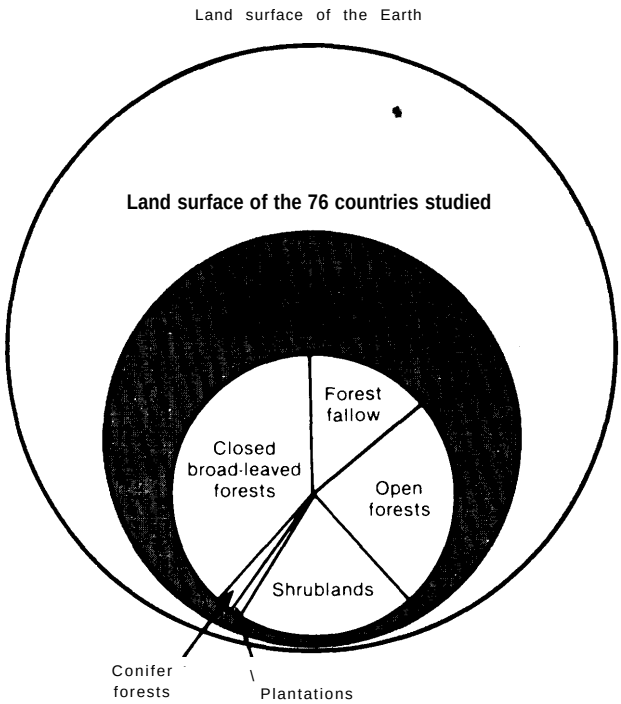
Forest Fallw

The closed tropical forest regions include some **240** million ha of land in forest fallow. Overall about 1 in 6 ha in the closed forests are being used for shifting agriculture. But in many nations, shifting agriculture has claimed a larger part of the closed forest. Sierra Leone has five times as much forest fallow as closed forest, Five other nations in tropical Africa, four in tropical Asia, and four in tropical America have from 50 to 100 percent as much forest fallow as closed forest, Table A-4 in appendix A shows the ratio of forest fallow to forest for each of the 76 nations. It is likely that much of this fallow land will not be returned to forest uses. Under unfavorable site conditions and short fallow periods, much of this land may eventually become unproductive for agriculture as well.

Estimates of forest fallow areas are not accurate. However, shifting agriculture is by no means limited to moist areas. In dry regions, fallow serves to restore moisture as well as organic matter and plant nutrients to the soil. The FAO/UNEP report estimates that about one-fifth of the land reported to be open forest is in fact forest fallow. Livestock graze on both the forest fallow and the open forest that has not yet been used for crops.

Figure 14 shows relative areas of each vegetation type for the 76 nations as a whole.

Figure 14.—Overall Area of Tropical Woody Vegetation



SOURCE: Food and Agriculture Organization/United Nations Environment Programme, *Tropical forest Resources Assessment Project (GEMS): Tropical Africa, Tropical Asia,* Tropical America, 4 VOIS. (Rome: FAO, 1981)

FOREST MANAGEMENT

Forest Logislation and Policy

Forest legislation and policy are evolving in tropical countries to reflect a growing awareness of the social and environmental implications of forestry decisions. Many tropical nations substantially revised their forestry laws during the 1960's and 1970's. In many cases, however, the laws look good on paper, but are not well-enforced (7).

Some issues have become more prominent in the last 5 to 10 years. For example, many countries have revised their logging laws and policies to be more restrictive regarding timber allocation from public land, lease terms, concession fees and taxes, annual allowable cut limits, regeneration methods, and export of unprocessed logs.

Other prominent policy issues include accelerating reforestation on degraded lands, protecting watersheds, increasing incentives for industrial plantations and farm forestry, and legislative support for reforesting communal land. Social issues, too, increasingly are being recognized (e.g., the needs of slash-and-burn cultivators and nomadic grazers, domestic fuelwood requirements, and release of forest lands to settled agriculture). Many tropical countries now view conservation as important to economic development and, thus, are more aware of the need to sustain multiple-use of forests, preserve biological diversity, maintain parks and protected areas, and guard against the loss of mangroves.

Some gaps, however, still need to be addressed. There is a need to evaluate tropical

forest resource policy, but no organization has such a program. The connection between forests and policies in other sectors such as land tenure and agrarian reform also needs to be assessed.

Forest Ownership

In order to understand the use and loss of forest resources and to devise effective policies for managing forests, it is important to know the legal and de facto ownership of forest lands and trees. The legal status of land may not indicate who has practical control of land use. For example, owners of large properties may appropriate adjoining public lands. Also, slash-and-burn cultivators and other landless poor may occupy communal forests. In fact, tree tenure may differ from land tenure.

The FAO/UNEP report (3) summarizes forest ownership by regions and provides some details at the national level. In tropical America, forest ownerships may be public, private, or communal. Most conifer forests in Brazil and in Central American nations are privately owned. The much larger broadleaved forests are public property, but national laws regarding forest ownership often are contradicted by local practice.

The situation is more complex in tropical Africa where private ownership of forests is rare. Traditional use rights in most forest areas are recognized for hunting, gathering nonwood products, acquisition of fuelwood and construction wood, and shifting cultivation or grazing. People may have exclusive rights over trees that they plant on communal lands. Local community ownership of forest lands in many former British colonies is recognized in national forestry laws. In former French colonies, local rights are not recognized at the national level and all forests are considered state property.

In tropical Asia, 80 to 90 percent of the forest land is state-owned and under the legal control of the forest departments. However, a large part of this land is illegally occupied by forest farmers, both those who practice traditional shifting agriculture and those who try to use the forest land for continuous cropping and grazing. State control over forest lands has been a gradual process, taking place mainly over the past 30 years. The central government in Nepal and some states in India such as West Bengal took control of all forested land from the villages in the 1950's. Papua New Guinea and most of the Pacific Islands are exceptions to this general rule. There, forests are owned by clans and tribes and the government has to negotiate with them for the right to use forest resources.

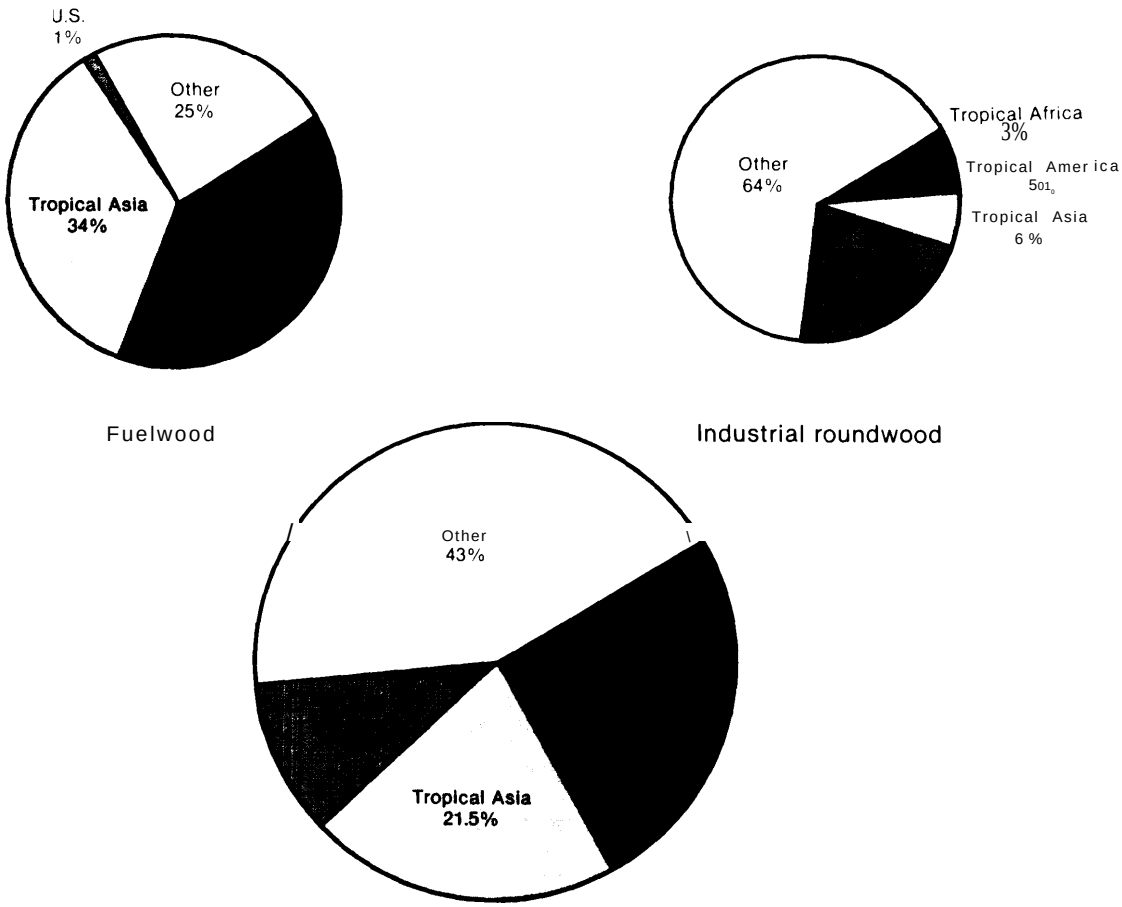
Wood Production

The 76 nations covered by the FAO/UNEP study of tropical forests produce 1.4 billion cubic meters of wood annually (measured as round logs extracted from the forest). As figure 15 indicates, this is about half of all the wood production in the world, and most (86 percent) of it is used for firewood or charcoal. The rest is "industrial wood" used for domestic and export production of sawlogs, veneer logs, lumber, poles, pulpwood, wood panels, and other processed products. Figure 16 indicates changes in wood production for each of the tropical regions over a 12-year period.

The production of industrial wood varies with economic conditions. Generally economic development during the 1970's, resulted in increasing demand for industrial wood in all the tropical regions. Industrial wood production increased most rapidly in tropical Asia and in West Africa with the growth of markets for sawlogs and veneer logs from those regions. More recently, slowing economies have constrained the growth in production. If rapid economic growth resumes, tropical America may experience substantial industrial wood production increases.

Significant investments were made in mills and infrastructure during the 1970's, but these have operated below capacity because of weak markets. In Asia and West Africa, depletion of resources is likely to constrain sawlog and veneer log production, but resurgence of economic growth should create domestic

Figure 15.—Comparative Production of Wood, 1980



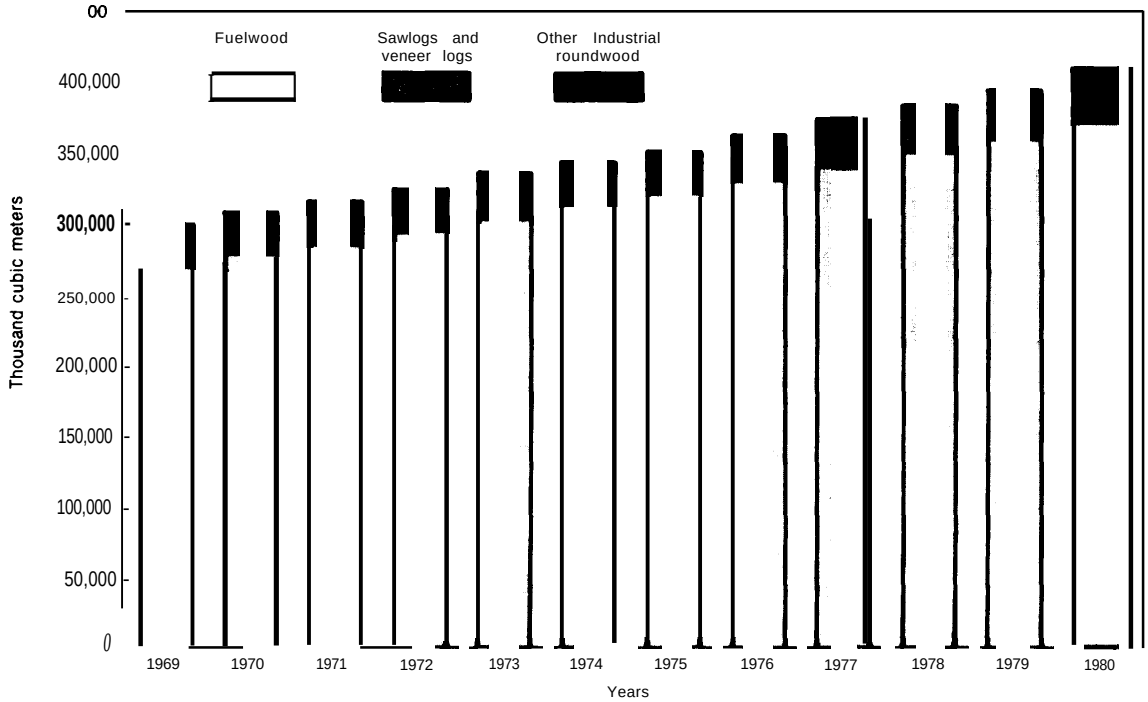
SOURCE: Adapted from Food and Agriculture Organization/United Nations Environment Programme, Tropical *Forest Resources,* Forestry Paper No 30 (Rome: FAO, 1982)

markets for wood chips to produce pulp and other wood products made from a wider variety of trees,

The increase in total wood production is driven by a steady increase in fuelwood production. However, the data on fuelwood apparently are obtained by multiplying unchanging estimates of per capita consumption by each country's population. Thus, the growth in production is probably not so steady as figure 16 suggests. Nevertheless, fuel is certainly the dominant use for wood in the Tropics and that dominance will become greater where economic growth continues to be slow.

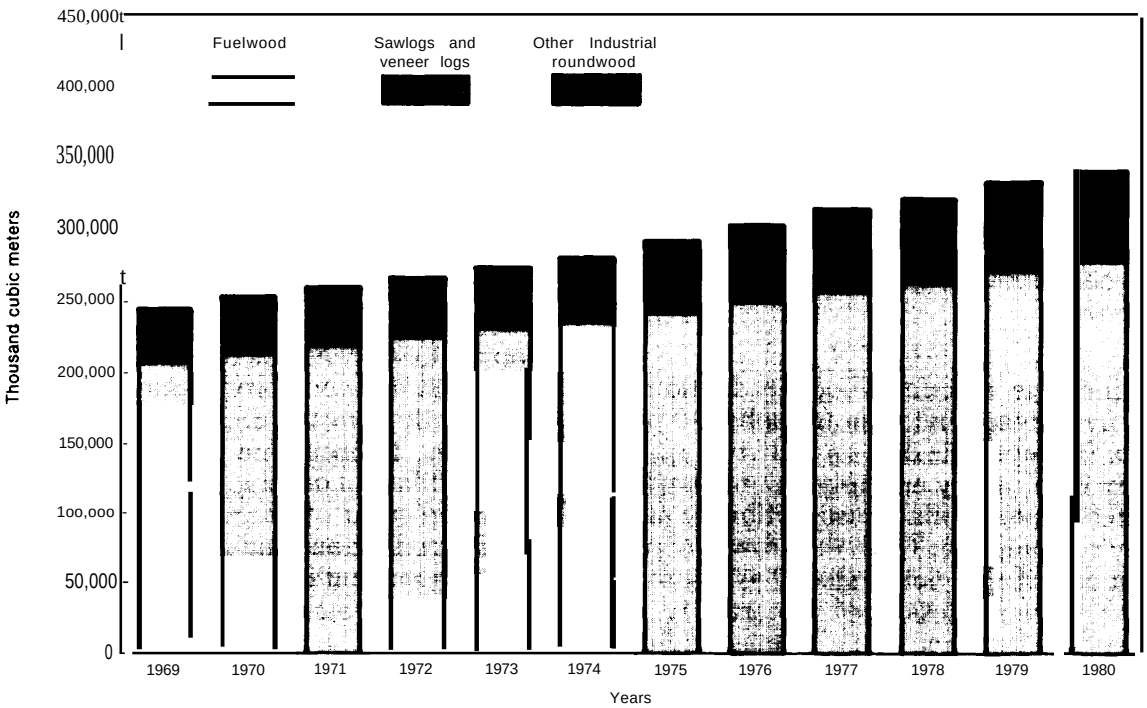
Looking at figure 16, one might expect that tropical forestry efforts would be concentrated mainly on fuelwood production. However, until recently forestry departments in tropical countries, international assistance agencies, and multilateral development banks have concentrated most of their efforts on industrial wood production. Industrial production attracts investment in the forestry sector because it can earn foreign exchange and concession fees, and it can be taxed. Thus, industrial wood

Figure 16/L-Wood Production in Tropical Africa, 1969-80



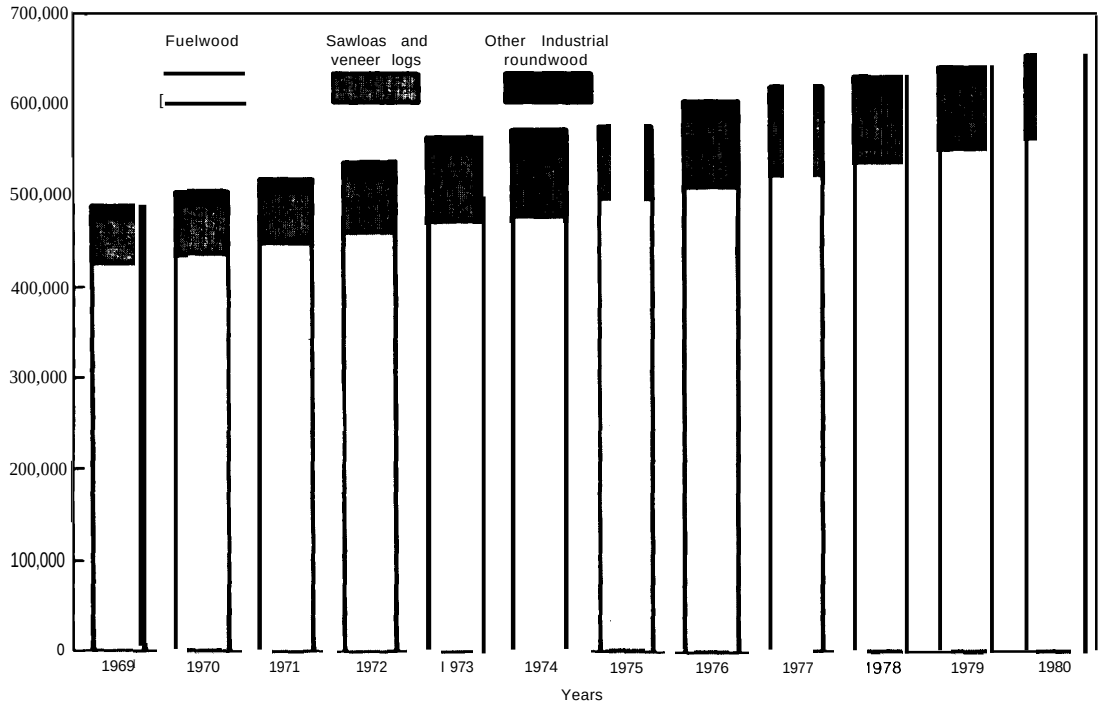
SOURCE Adapted from Food and Agriculture Organization/United Nations Environment Programme, *Tropical Forest Resources,* Forestry Paper No. 30 (Rome: FAO, 1982)

Figure 16 B.–Wood Production in Tropical America, 1969.80



SOURCE' Adapted from Food and Agriculture Organization/United Nations Environment Programme, *Tropical Forest Resources,* Forestry Paper No, 30 (Rome: FAO, 1982)

Figure 16C.–Wood Production in Tropical Asia, 1969-80



SOURCE dated from Food and Agriculture Organlzatlon/United Nations Environment Program me, *Tropical Foresf Resources* Forestry Paper No 30 (Rome FAO. 1982)

production probably will continue to dominate tropical forestry activities.

The problem of ensuring an adequate industrial wood supply for international trade* is more tractable than problems associated with fuelwood supply, impacts of deforestation on soil and water resources, or maintenance of biological diversity. First, nearly 75 percent of the world's industrial wood is now produced in the temperate zone. Second, industrial wood supplies have grown at reasonably stable rates for 30 years (9). And third, a large proportion of the world's future consumption of industrial wood can come from plantations. One recent estimate is that 140 million ha of well-managed plantations could, theoretically, supply all the industrial wood consumed in the world in the year 2000 (8). That would be an area equal to 5 percent of the present forested area in the world.

*See the OTA assessment *Wood Use: U.S. Competitiveness and Technology*, OTA-ITE-210, August 1983, for an analysis of world markets for industrial woods.

Much more wood is consumed in tropical countries for fuelwood, however. Serious shortages of fuelwood, lumber, poles, paper, and other forest products within nations are not being met through international trade because of high transportation costs and persistent poverty. Furthermore, conflicts between forest and agricultural land uses are critical in many countries.

Natural Forest Management

Only small areas of tropical forests are under intensive management (3). In tropical America, management is increasing. For example, Mexico is managing watershed forests through controlled logging. Belize, Brazil, Guatemala, and Paraguay are designing management plans for natural resources. Silvicultural trials and research efforts to develop suitable technologies for managing natural forests are under way in Brazil, Costa Rica, French Guyana, Mexico, Peru, and Venezuela.

Some African nations, when they were British and Belgian colonies, had developed harvesting regulations and working plans for managing natural forests, but these have been abandoned over the past two decades. Nigeria, Zaire, and Tanzania previously managed large areas of natural forest, but no longer do so. Uganda reports a large managed area, although it is doubtful that the management plans have been implemented. The Congo also is preparing plans that set the allowable cut for natural forests and indicate appropriate silvicultural practices.

The deciduous and conifer forests of South Asia—Burma, Bangladesh, India, and Pakistan—have a long history of intensive forest management. India alone contains 60 percent of all the managed forest in the 76 tropical nations. However, the remaining tropical forests of South Asia and the forests of Southeast Asia are not intensively managed for a number of reasons. Information on forest ecology and dynamics is scarce. Forestry departments lack trained personnel to manage the forests. The emphasis in forestry has been on commercial exploitation so that little attention has been given to silvicultural treatments (3).

Plantations

About 11.5 million ha of tree plantations had been established in the 76 nations by the end of 1980 (table A-5 in app. A). Most (68 percent) of these are in just three countries: Brazil, India, and Indonesia. About 7 million ha are intended to produce sawlogs, veneerlogs, pulpwood, or industrial poles. Only 4.4 million ha have been planted for fuelwood and charcoal, for environmental protection, and for nonwood products such as gum arabic.

The estimated rate of planting in the tropical nations is about 1.1 million ha/yr (4). Current planting is intended mainly (53 percent) for lumber, paper, and industrial poles, but a gradual shift to fast-growing trees to produce fuelwood and charcoal is occurring as a result of changing objectives in tropical forestry.

Forestry plantations are usually monoculture, often of exotic species, planted not where forest cutting is occurring, but rather on land that has been cleared for some time, such as abandoned farmland (5). Most industrial wood plantations in East Africa are softwoods (pines and cypress), while in West Africa hardwoods (principally teak) are planted. In tropical America, pines are usually grown for saw timber, while eucalyptus and gmelina are planted for pulpwood. Eucalyptus frequently is grown for pulpwood in India, while teak is grown for timber in India and Indonesia.

Two-thirds of nonindustrial plantations in Africa are for fuelwood; the rest are mainly for gum arabic production or watershed protection. In tropical America, three-quarters of the plantations classified as nonindustrial are eucalyptus trees planted to supply charcoal to the iron and steel industry in the Brazilian State of Minas Gerais. Most of the rest is for production of forest fruit, such as "palmito." Only about 100,000 ha of plantations in tropical America are intended primarily for soil and watershed protection; Mexico has most of these. In Asia, most nonindustrial plantations are intended to produce locally consumed firewood and these are being planted at a rate of about 1 million ha/yr.

The rate of forest plantation establishment is much too low to replace the amount of forest being cleared. In tropical America, the ratio of area planted to area deforested annually is about 1 to 10.5; in tropical Africa it is 1 to 29; and in tropical Asia it is 1 to 4.5 (4). Furthermore, most reforestation programs are not carried out where deforestation takes place. In Brazil, for example, plantations are concentrated in the South, whereas forest clearing occurs mainly in the North.

The greatest discrepancy between reforestation rates and the demand for wood and other forest products is in Africa. In Asia, reforestation is closer to deforestation because deforestation rates level off as the remaining forest is left only in inaccessible areas and because severe wood shortages in heavily populated areas are leading to greater planting efforts (4).

DESTRUCTION OF FOREST RESOURCES

Distinguishing between deforestation (also called "clearing" in this report) and degradation of forest resources is important. The FAO/UNEP study estimates deforestation rates for 1976-80 and projects rate estimates for 1981-85. It does not, however, estimate degradation rates. Unlike deforestation, degradation is not easy to identify through time-series Landsat or other remote-sensing analyses.

Deforestation

Each year about 0.5 percent of the remaining closed tropical forests and 0.6 percent of the remaining open tropical forests are converted to nonforest land uses or to wasteland. This is an aggregation of estimated deforestation rates from the 76 countries covered by the FAO/UNEP report. In some countries, the deforestation rate has been estimated by comparing Landsat or other remote-sensing data from two time periods; for some, information on population growth, farming, and animal husbandry practices were considered as well. Table A-6 in appendix A shows estimated areas of closed forest converted to nonforest annually for each of the 76 countries.

Deforestation and Degradation

Much of the confusion over rates of change in forest areas stems from the failure to distinguish between deforestation and degradation. As defined here and in the FAO/UNEP report:

- Deforestation is the conversion of forests to land uses that have a tree cover of less than 10 percent. Thus, logged-over areas, including clear-cut areas, are not classified as deforested if the forest is in the process of regenerating.
- Degradation of forests refers to biological, physical, and chemical processes that result in loss of the productive potential of natural resources in areas that remain classified as forest. Soil erosion and Ioss of valuable or potentially valuable genetic types are examples of degradation. In some cases, forests can recover naturally from degradation within a few decades. In other cases recovery may take much longer, if it occurs at all.

The overall tropical deforestation rate is strongly affected by the status of the forests in a few tropical nations that have very large forest areas relative to their population. Thus, the 0.5 and 0.6 percent/yr figures obscure both substantial differences among nations and the overall severity of tropical deforestation. Closed forest area per capita is already less than O.O5 ha in 17 of the 76 nations. Over half the rest have deforestation rates between 1 and 6.5 percent/yr. Table 3 indicates forest areas per capita and deforestation rate estimates for each country.

Table 4 shows the 76 nations divided into nine categories of closed forest area and population size. Several countries, including Gabon, Congo, French Guiana, Surinam, and Guyana, have such large forests and so few people that their deforestation rates are very low. Clearly, closed tropical forests will exist in these nations for many decades, although even a relatively small population can cause resource degradation over large areas. Other nations, such as Liberia and Honduras, have large amounts of forest but also have high deforestation rates. If current rates of deforestation and population growth were to continue, these two nations would, in just 15 years, reduce their forest area per capita to half what it is. In some nations, deforestation can be expected to slow as the forests are reduced to inaccessible areas that are unattractive to farmers. However, experience in nations such as Haiti, El Salvador, Jamaica, Costa Rica, Nepal, Sri Lanka, Angola, and Ghana indicate that deforestation can continue rapidly even when only limited forests remain.

In tropical Africa, deforestation rates are highest in the West African nations. Nigeria and Ivory Coast together incur almost half (45 percent) of the continent's total annual deforestation of closed forests, About 4 percent of the closed forests of the West African nations

Table 3.—Estimates of Per Capita Closed Forest Areas and Deforestation Rates in Tropical Africa, America, and Asia

Country	Closed forest area (1,000 ha)	Closed forest area (ha) per capita	Percent deforested per year[a]
Tropicai Africa:			
Ivory Coast	4,458	0.5	6.5
Nigeria	5,950	0.7	5.0
Rwanda	120		2.7
Burundi	26	[b]	2.7
Benin	47	[b]	2.6
Guinea-Bissau	660	0.8	2.6
Liberia	2,000	1.0	2.3
Guinea	2,050	0.4	1.8
Kenya	1,105	0.1	1.7
Madagascar	10,300	1.1	1.5
Angola	2,900	0.4	1.5
Uganda	765	0.1	1.3
Zambia	3,010	0.5	1.3
Ghana	1,718	0.1	1.3
Mozambique	935	0.1	1.1
Sierra Leone	740	0.2	0.8
Tanzania	1,440	0.1	0.7
Togo	304	0.1	0.7
Sudan	650		0.6
Chad	500	0.1	0.4
Cameroon	17,920	2.0	0.4
Ethiopia	4,350	0.1	0.2
Somalia	1,540	0.3	0.2
Equatorial Guinea	1,295	4.3	0.2
Zaire	105,750	3.4	0.2
Central African Republic	3,590	1.4	0.1
Gabon	20,500	29.3	0.1
Congo	21.340	12.6	0.1
Zimbabwe	'200	[b]	[c]
Namibia	[c]	[b]	[c]
Botswana	[c]	[b]	[c]
Mali	[c]	[b]	[c]
Upper Volta	[c]	[b]	[c]
Niger	[c]	[b]	[c]
Senegal	220	[b]	[c]
Malawi	186	[b]	[c]
Gambia	65	0.1	[c]
Totals	216.634	0.6	0.61
Tropical America:			
Paraguay	4,070	1.2	4.7
Costa Rica	1,638	0.7	4.0
Haiti	48		3.8
El Salvador	141	[b]	3.2
Jamaica	67	[b]	3.0
Nicaragua	4,496	1.6	2.7
Ecuador	14,250	1.6	2.4
Honduras	3,797	0.9	2.4
Guatemala	4,442	0.6	2.0
Colombia	46,400	1.7	1.8
Mexico	46,250	0.6	1.3
Panama	4,165	2.0	0.9
Belize	1,354	5.0	0.7
Dominican Republic	629	0.1	0.6
Trinidad and Tobago	208	0.2	0.4
Peru	69,680	3.6	0.4
Brazil	357,480	2.7	0.4
Venezuela	31,870	1.8	0.4
Bolivia	44,010	7.5	0.2
Cuba	1,455	0.1	0.1
French Guiana	8,900	129.1	[c]
Surinam	14,830	37.1	[c]
Guyana	18,475	23.1	[c]
Totals	678,655	2.1	0.6
Tropical Asia:			
Nepal	1,941	0.1	4.3
Sri Lanka	1,659	0.1	3.5
Thailand	9,235	0.2	2.7
Brunei	323	1.2	1.5
Malaysia	20,995	1.4	1.2
Laos	8,410	2.3	1.2
Philippines	9,510	0.2	1.0
Bangladesh	927	[b]	0.9
Viet Nab	8,770	0.2	0.7
Indonesia	113,895	0.7	0.5
Pakistan	2,185	[b]	0.3
Burma	31,941	0.8	0.3
Kampuchea	7,548	1.3	0.3
India	51,841	0.1	0.3
Bhutan	2,100	1.5	0.1
Papua New Guinea	34,230	11.0	0.1
Totals	305,510	0.2	0.6

[a]From 1981-85.
[b]Lessthan 0.05 forest hectares per capita.
[c]No data; in most cases this is where the areas are very small.

SOURCES: Population Reference Bureau, World *Population Data Sheet* Washington, D.C; Food and Agriculture Organization/United Nations Environment Programme, Tropical Forest Resources AssessrnenfF'reject (GEMS): Tropical Africa, Tropical Asia, Tropical Arnerica,4 vols. (Rome: FAO, 1981)

are deforested each year. Other African regions with high deforestation rates include East Africa, where 1.4 percent of the closed forest capable of producing industrial wood is cleared each year, and the nations of Burundi and Rwanda, where the rate is 2.7 percent/yr. Large areas of closed forest in Zaire and Cameroon are cleared—262,000 ha/yr together—but like Brazil these countries are forest-rich so the rates do not seem so alarming as in the other African nations.

Five nations in tropical America (Paraguay, Costa Rica, Haiti, El Salvador, and Jamaica) have deforestation rates of at least 3 percent/yr, while another six (Nicaragua, Ecuador, Honduras, Guatemala, Columbia, and Mexico)convert atleast l percent/yr of their closed forest to other uses or to unforested wasteland. Although deforestation in Brazil is low when expressed as a percent of the remaining forest(0.4 percent), it affects a large area—about l.5 million ha/yr. That is one-third of all the closed

Table 4.—Comparison of Tropical Countries' Closed Forest Sizes, population Sizes, and Deforestation Rates

Region/country	Closed forest size[a]	Population size[b]	Deforestation rate[c]
Tropical Africa:			
Kenya	Small	Large	1 ,7%
Uganda	Small	Large	1,3
Ghana	Small	Large	1.3
Mozambique	Small	Large	1.1
Tanzania	Small	Large	07
Sudan	Small	Large	06
Burundi	Small	Medium	27
Rwanda	Small	Medium	2.7
Benin	Small	Medium	26
Sierra Leone	Small	Medium	08
Chad	Small	Medium	04
Upper Volta	Small	Medium	d
Zimbabwe	Small	Medium	d
Mali	Small	Medium	d
Niger	Small	Medium	d
Senegal	Small	Medium	d
Malawi	Small	Medium	d
Guinea-Bissau	Small	Small	2.6
Togo	Small	Small	07
Equatorial Guinea	Small	Small	0.2
Botswana	Small	Small	d
Gambia	Small	Small	d
Namibia	Small	Small	d
Ivory Coast	Mediurn	Large	65
Nigeria	Medium	Large	5.0
Angola	Medium	Large	15
Ethiopia	Medium	Large	02
Guinea	Medium	Medium	1.8
Zambia	Medium	Medium	1.3
Somalia	Medium	Medium	02
Liberia	Medium	Small	2.3
Central African Republic	Medium	Small	0.1
Madagascar	Large	Large	1,5
Cameroon	Large	Large	0.4
Zaire	Large	Large	0,2
Gabon	Large	Small	0.1
Congo	Large	Small	01
Tropical America:			
Cuba	Small	Large	01
Haiti	Small	Medium	38
El Salvador	Small	Medium	32
Dominican Republic	Small	Medium	06
Costa Rica	Small	Small	2.0
Jamaica	Small	Small	3.0
Belize	Small	Small	0.7
Trinidad and Tobago	Small	Small	0.4
Guatemala	Medium	Large	2.0
Paraguay	Medium	Medium	4.7
Honduras	Medium	Medium	2.4
Nicaragua	Medium	Small	2.7
Panama	Medium	Small	0.9
Ecuador	Large	Large	2.4
Colombia	Large	Large	1.8
Mexico	Large	Large	1.3
Venezuela	Large	Large	0.4
Peru	Large	Large	0.4
Brazil	Large	Large	0.4
Bolivia	Large	Large	0.2
Surinam	Large	Small	d
Guyana	Large	Small	d
French Guiana	Large	Small	d
Tropical Asia:			
Nepal	Small	Large	4.3
Sri Lanka	Small	Large	3.5
Brunei	Small	Large	1.5
Bangladesh	Small	Large	0.9
Pakistan	Medium	Large	0.3
Bhutan	Medium	Small	0.1
Laos	Large	Medium	1.2
Kampuchea	Large	Medium	0.3
Papua New Guinea	Large	Medium	0.1
Thailand	Large	Large	2.7
Malaysia	Large	Large	1.2
Philippines	Large	Large	1.0
Viet Nam	Large	Large	0.7
Indonesia	Large	Large	0.5
Burma	Large	Large	0.3
India	Large	Large	0.3

[a]Closed forest size classes for this table are: large—more than 6 million hectares; medium—2 to 6 million hectares; small—less than 2 million hectares
[b]Population size classes for this table are: large—more than 7.5 million people; medium—3 to 7.5 million people; small—less than 3 million people.
[c]Deforestation rate is the percent of the 1980 closed forest area that is being cleared each year during 1981 to 1985.
[d]Indicates the annual deforestation rate is less than 0.05 percent.

SOURCES: Population Reference Bureau, *1983 World Population Data Sheet*. Food and Agriculture Organization/United Nations Environmental Programme. *Tropical Forests Resources Assessment Project (GEMS): Tropical Asia, Tropical America, Tropical Africa*, 4 vols. (Rome: FAO, 1981).

forest clearing each year in tropical America. Colombia and Mexico together account for another third.

Three-fifths of the closed forest cleared in tropical Asia each year is logged-over productive forest and about one-quarter is previously undisturbed forests. The highest deforestation rate in Asia is 4.3 percent/yr in Nepal, and a significant portion of this cutting occurs in temperate forests on mountain watersheds. In Sri Lanka, deforestation is 3.5 percent/yr, and in Thailand it is 2.7 percent. Brunei, the Philippines, and Bangladesh also have very high deforestation rates.

Rates of deforestation are calculated as the estimated area deforested per year divided by the estimated 1980 forest area. Thus, these rates should not be confused with geometric rates of change, such as population growth rates. Acceleration or deceleration of deforestation rates are influenced not only by population growth but also by many other factors such as rural to urban migration rates, land tenure changes, and especially road-building activities. Much too little is known about how these factors interact to predict how deforestation rates will change over any long period.

The FAO/UNEP study does draw some inferences about changes in the accessibility of the remaining forests. The area of closed tropical forest cleared each year may be decreasing slightly for tropical Africa as a whole during the first half of the 1980's, since during the previous decade the closed forests in heavily populated countries of West Africa generally were reduced to sites that are unattractive to farmers. However, the rate probably is accelerating in some nations. Deforestation in Latin America, on the other hand, probably is increasing because additional forested areas are becoming accessible as new roads and bridges are built. In tropical Asia, deforestation is also thought to be increasing, but the rate probably will level off in the 1990's as the forests are reduced to inaccessible areas or sites where agricultural clearing is not worthwhile.

Based on current and planned rates of tree plantation establishment, the areas reforested in the Tropics as a whole are about one-tenth of the areas deforested.

Deforestation also occurs in open tropical forests, Trees are cut and burned both by traditional shifting agriculturists and by farmers intending to establish permanent croplands. Extracting wood for fuel or industrial use, fires, and excessive grazing all cause deforestation by reducing tree cover to less than 10 percent. The open forest area data are poor, however, and the estimates of deforestation rates are even less precise. Deforestation in the dry open forests is typically a gradual process and thus is more difficult to see than in moist areas where the tree canopies are more dense. Further, the open forest lands are often under the jurisdiction of agencies that consider grazing to be the main use of this land. Thus, the land is likely to be classified by its herbaceous cover rather than its tree cover.

The FAO/UNEP study does not list country-specific deforestation rates for open forests, but it does provide overall estimates of open forest clearing for tropical Africa, America, and Asia. These are shown in table 5. As a rough indicator of the pressure on open forest resources, table A-7 in appendix A indicates open forest area per capita for each of the 76 nations.

Resource Degradation

Resource degradation, the long-term loss of productive potential, is much more difficult to measure than deforestation. Reduction of soil quality and loss of superior genetic types of trees have been documented for specific forest locations (6). But so little is known about the ecology of the tropical forests or the economic potential of the many tropical forest species that degradation can be a highly subjective term. Forest resource degradation is undoubtedly occurring (3,6) and, especially in the drier open forests where recovery is slower, it may be a more important change than deforestation (12),

Table 5.—Annual Deforestation, 1981-85

	Closed forests						Open forests		Total open and closed forests		Area reforested annually
	Undisturbed		Productive, logged		Unproductive						
	(1,000 ha)	(%)	(1,000 ha)	(%)	(1,000 ha)	(%)	(1,000 ha)	(%)	(1,000 ha)	(%)	(1,000 ha)
Tropical America .	1,299	0.29	1,867	2.78	1,173	0.74	1,272	0.59	5,611	0.63	535
Tropical Africa . . .	226	0.19	1,032	2.31	73	0.14	2,345	0.98	3,676	0.52	126
Tropical Asia.	395	0.39	1,278	1.28	153	0.15	190	0.61	2,016	0.60	438
Total	1,920	0.28	4,177	1.98	1,399	0.45	3,807	0.52	11,303	0.58	1,099

SOURCE Calculated from Food and Agriculture Organlz~lon/United Nations Ennvironment Programme, *Tropical Forest Resources,* Forestry Paper No 30 (Rome FAO, 1982)

Forest resource degradation has multiple causes. Logging practices can cause degradation by damaging residual trees, damaging soil, or failing to create an environment where natural regeneration of valuable forest species can occur. Forests in tropical America and Africa typically contain a large number of tree species per hectare, but just a few are commercially valuable for timber. Logging in these areas usually means felling and extracting only the best-shaped, large individuals of selected species. Yet, substantial and lasting damage is often done to the residual trees as a result of mechanized logging and skidding operations (10). As much as one-half of the residual stand may be damaged (e.g., broken stems and branches or disturbed roots) and one-third of the logged area may undergo soil damage (2).

Some tropical forests, such as the *Dipterocarp* forests of South and Southeast Asia, have a large number of commercially valuable species per hectare and are clearcut. This can cause soil erosion that reduces the potential for natural regeneration. In tropical moist forests a large proportion of the ecosystem's nutrients are tied up within the biomass of trees rather than the soils (fig. 17). Thus, a large share of the nutrients may be exported from the forest with the logs. Machinery is available to harvest whole trees and to use multiple species to produce pulpwood. Although these technologies are not yet widely used in the Tropics, they could accelerate the loss of soil fertility (2). Furthermore, many tropical tree species seed irregularly or at long intervals (once in 5 to 7 years). If clearcutting is practiced, natural regeneration of these species may not occur. Clearcutting also reduces regeneration of trees, such as Dipterocarps, whose seedlings need to grow in partial shade (l).

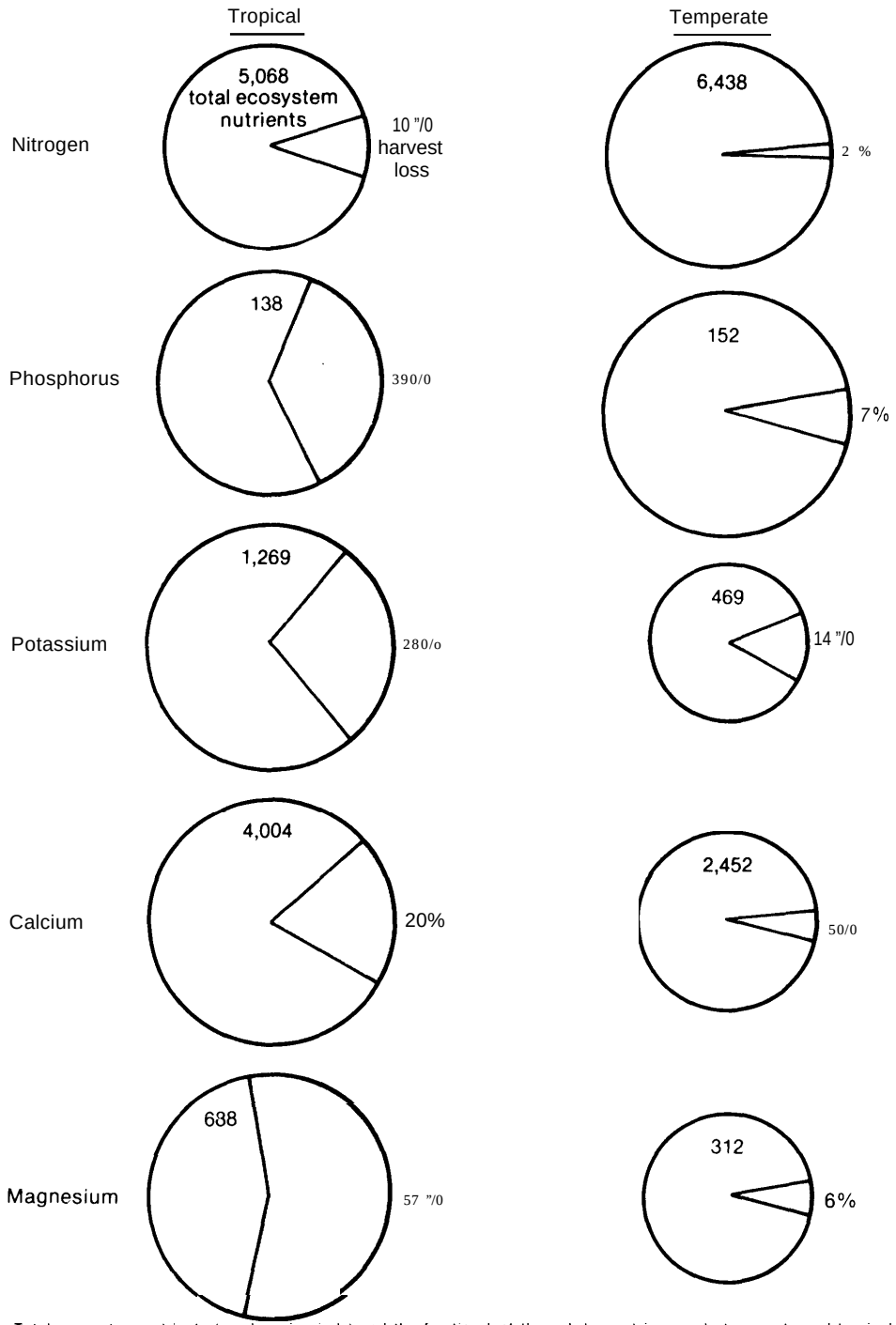
Conifer and mangrove forests in all three tropical regions and certain other forests in tropical America (e.g., "cativo" and "sanjo" forests of Panama and Colombia) also have a low diversity and often are clearcut or cutover so severely that soil conditions are unable to support natural regeneration.

Even where clearcutting is not practiced, logging roads can lead to degradation, For example, in Sabah and the Philippines, approximately 14 percent of forest concession areas are cleared for logging roads (3). *Poorly* designed or constructed roads cause erosion and water drainage problems and may increase the severity of Landslides,

Projection OF CHANGES

The FAO/UNEP study provides some estimates of rates at which forests are being changed from one category to another during the period 1980-85, although quantitative data on natural resource degradation in areas that remain classified as forest are not available. A straight-line projection of the FAO/UNEP estimates, while not a forecast, can provide an understandable way to describe the magnitude of resource changes that may occur. Table 6 shows the projected forest areas for each of the three tropical regions.

Figure 17.—Plant Nutrient Loss Caused by Logging in Tropical v. Temperate Forests



Total ecosystem nutrients (numbers in circle) and the fraction lost through harvest in sample temperate and tropical orests. Values are kilograms per hectare. Shaded area indicates the amount removed when trees are harvested (boles only), ıssuming that all roots, branches, and leaves remain in the forest.

Temperate data are a mean of four kinds of vegetation from Ovington (1962): *Pinus sylvestris, Pseudotsuga taxifolia, Betula 'errucosa,* and *Quercus robur.* Tropical data are a mean of data from Kade, Nigeria and Yangambi, Zaire (summarized in Nye ınd Greenland, 1960) plus Puerto Rico (Odum and Pigeon, 1970).

SOURCE: J. Ewel and E. Conde, "Environmental Implications of Any-Species Utilization in Moist Tropics," paper for Conference on Improved Utilization of Tropical Forests, Madison, Wis., 1978, pp. 63-82.

Table 6.–Forest Area Projections (1,000 ha)

Forest Category	Tropical Africa 1980a	1985a	2000b	Change over 20 years (o/.)	Tropical America 1980a	1985a	2000b	Change over 20 years (o/o)	Tropical Asia 1980a	1985a	2000b	Change over 20 years (%)
Closed forests:												
Undisturbed, productive	118,450	114,134	101,186	–15	454,507	438,119	388,995	–14	101,352	89,087	52,292	–48
Logged, productive	42,848	40,911	35,100	–18	66,622	67,281	69,258	+4	59,847	60,424	62,155	+4
Managed, productive	1,735	1,689	1,551	–11	522	522	522	0	39.790	40,032	40,758	+ 2
Fallow In closed forests	61,646	66,705	81,882	+33	108.612	116,303	139,376	+28	69,225	73.729	87.241	+26
Physically unproductive or parks and protected areas	53,601	53,236	52,141	–3	157,004	151,140	133,548	–15	104,521	106,836	113,781	+9
Open forests:												
Productive	169,218	159,555	130,566	–23	142,887	136,787	118,487	–17	8,530	8,075	6,710	–21
Unproductive	317,227	315,167	308,987	– 3	74,110	73,850	73,070	– 1	22,418	21,923	20,438	-9
Fallow In open forests	104,335	111,520	133,075	+28	61,650	62,950	66,850	+8	3,990	4,100	4.430	+11

[a]SOURCE Food and Agriculture Organ!zat!on/United Nat Ions Environment Program me, Tropica/ *Forest Resources,* Forestry Paper No 30 (Rome FAO, 1982)
[b]Extrapolated from current rates of change excludes plantations

This 20-year projection suggests that at current rates of logging and deforestation in tropical Africa, the area of undisturbed forest would decline 15 percent by the year 2000. Some of this is because timber harvest will convert undisturbed forest to logged forest. The logged forest category also includes secondary forest on land that is recovering from use for shifting agriculture. However, in spite of these additions, the logged forest area is decreasing because this category incurs most of the deforestation for agriculture, Since the land does not sustain continuous cropping, the forest fallow area is expected to increase over the 20-year period by one-third. Changes in the open forests of Africa would be even greater. The open forest fallow is already larger than the fallow area in Africa's closed tropical forests. It would increase by another 28 million ha as productive open forest is degraded to the unproductive category and both are cleared for shifting agriculture.

The projection shows a 14-percent reduction in the area of productive undisturbed forest in tropical America, It also shows a 4 percent increase in the area of logged forest, which suggests that logging of undisturbed forest outpaces clearing of logged forest only slightly. Meanwhile, the forest fallow area in tropical America would increase by only about half as many hectares as are lost from the forest categories, implying that large areas are being converted to nonforest uses other than shifting agriculture. The main reason for converting forest land in tropical America in recent years has been to make cattle pasture, although this use generally is not sustainable in moist forest areas. The area of closed forest that is unproductive for physical or legal reasons is also declining significantly, suggesting that this land is not so inaccessible as its definition implies.

The change rates for tropical America's open forests imply degradation of forest from the productive category, simultaneous clearing of the unproductive forest, and a net increase in open forest fallow that can account for only a fraction of the reduction in the forest categories. Again, this means a net conversion of open forest into cropland, grazing land, and degraded land where forests do not regenerate naturally, and it means a substantial decline in the quality of the remaining open forest.

Tropical Asia shows the highest reduction (21 percent) in undisturbed productive forest, although such forest has already been reduced to an area much smaller than in tropical Africa and America. The logged-over area is increasing slightly, probably because forestry departments in several Asian nations have some control over the spontaneous clearing for cropland that follows logging operations, The area of forests unproductive for physical or legal reasons is increasing in tropical Asia, though whether this is a result of more parks being established or of severe degradation of the logged-over forests is not clear. Open forests in tropical Asia are not so extensive as in

the other regions, but the pattern of degradation and deforestation is similar.

Reviewing the FAO/UNEP study's findings on deforestation and resource degradation, westoby (12) declares that the situation is most alarming in the drier areas, where the data are least precise:

> Among the one and a half thousand million or so hectares of open forest and shrub land, there is an infinite gradation of forest and shrub, ranging from less dry and reasonably wooded forests at one end to extremely arid shrub formations at the other, with the borderline between what can still be regarded as forest and what is irretrievably lost, vague, difficult to identify from aerial photography or satellite imagery, and by no means easy to be sure about when one is actually there standing in it. What is happening to these forests today, under the impact of a variety of pressures, can best be visualized as a steady pushing along the spectrum, a general downgrading, with the result that very substantial areas every year slide out of sight and can no longer be considered as forest on even the most generous definition. But what should be giving concern is not so much the 4 million or so hectares that are sliding off the visible spectrum as the general degradation which is sapping away at the drier tropical forests through the whole spectrum,

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