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ABSTRACT

This document deals with efforts aimed at reforesting large areas of degraded lands. It includes sections on: (1) tree cover trends; (2) fuelwood challenges of the future; (3) the need to supply industrial wood; (4) stabilizing soil and water resources; (5) forests and climate change; and (6) mobilization for reforestation. (TW)

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# Reforesting the Earth

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Before the dawn of agriculture, some 10,000 years ago, the earth boasted a rich mantle of forest and open woodland covering roughly 6.2 billion hectares. Over time, a combination of land clearing for crop production, fuelwood gathering, commercial timber harvesting, and cattle ranching has caused the earth's forests to shrink to some 4.1 billion hectares—a third less than existed in preagricultural times.[1]

For centuries, this reduction in the earth's biological stock hindered human progress little, if at all. Indeed, the clearing of trees to expand food production and the harvesting of forest products were vital aspects of economic and social development. But in recent years the relentless loss of tree cover has begun to impinge directly on the economic and environmental health of numerous nations, mostly in the Third World. Combined with concerted efforts to protect remaining forests, large-scale reforestation—a seeming anomaly for a planet where woody vegetation still covers 40 percent of the land—now appears essential to improving the human prospect.

Most tree planting efforts over the last several decades have aimed at increasing supplies of marketable timber, pulp, and fuelwood for cities—wood products that yield tangible economic benefits. By contrast, reforestation for reasons that lie outside the monetized economy has been vastly underattended. Yet trees quite literally form the roots of many natural systems. With the inexorable march of deforestation, the ecological integrity of many areas is disintegrating, causing severe soil loss, aggravating droughts and floods, disrupting water supplies, and reducing land productivity.

Trees are also a vital component of the survival economy of the rural poor. Hundreds of millions of people rely on gathered wood to cook their meals and heat their homes. For them, lack of access to wood translates into reduced living standards and, in some cases, directly into malnutrition. In addition, trees and soils play a crucial role in the

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global cycling of carbon, the importance of which has been magnified by the emergence of carbon dioxide-induced climate change as arguably the most threatening environmental problem of modern times.



Efforts to slow deforestation certainly deserve redoubled support. But even if forest clearing miraculously ceased today, millions of hectares of trees would still have to be planted to meet future fuelwood needs and to stabilize soil and water resources. Increased planting to satisfy rising demands for paper, lumber, and other industrial wood products, though less daunting a task, is also crucial. Expanding forest cover for all these reasons will reduce pressures on remaining virgin forest, helping to preserve habitats and thereby safeguard the earth's biological diversity. At the same time, it will mitigate the buildup of atmospheric carbon dioxide, which gives industrial countries sound reason to step up support for tree planting in the Third World.

Successfully reforesting large areas of degraded lands, however, will require much more than financial commitments from governments and international lending agencies. It will take effective coordination with numerous local groups in starting nurseries in thousands of villages and encouraging the planting of multipurpose trees along roads, on farms, and around houses. Only by garnering the knowledge, support, and energy of rural people themselves—and planting to meet their basic needs—is there any hope of success.

## Tree Cover Trends

Dramatic changes in regional forest cover historically reflect powerful societal transformations. Beginning in the sixteenth century, the expanding agricultural and industrial needs of Renaissance societies spurred the clearing of large tracts of forest in Western Europe. Both the French and the English so depleted their domestic forest resources that they were forced by the mid-seventeenth century to conduct a worldwide search for ship timbers in order to maintain their maritime superiority. France, once 80-percent forested, had trees covering only 14 percent of its territory by 1789. Similarly, forest

"Even if forest clearing miraculously ceased today, millions of hectares of trees would still have to be planted."

cover in what is now the contiguous United States totaled some 385 million hectares in 1630, about when the Pilgrims arrived. As colonization spread along the eastern seaboard and gradually westward, forests dwindled. By 1920, trees covered 249 million hectares, more than a third less than when European settlement began.[2]



Despite growing recognition of the importance of forests to the economic and ecological health of nations, surprisingly little is known with certainty about the state of forest resources today. Many countries have not fully inventoried their forests, and the data that do exist vary widely in quality. In 1981, the United Nations Food and Agriculture Organization (FAO) generated the first global assessment of tropical forests that reconciled all data to a standard classification scheme and a standard base year. This study, which included correspondence with 76 countries and selective use of satellite imagery, still provides the best information available on tropical forests, even though much of the data are more than a decade old.

Combining FAO's estimates for tropical forests with those of a 1985 forest assessment by the U.N. Economic Commission for Europe and with various individual country reports yields a rough picture of the global forest resource base. (See Table 1.) Closed forest, where the shade from tree crowns prevents substantial growth of grass, covers 2.8 billion hectares worldwide. Another 1.3 billion hectares are open woodlands, including, for example, the wooded savannah of Africa and the cerrado in Brazil. Collectively, then, forested lands cover approximately 4.1 billion hectares, an area almost triple that in crops. Shrubland and forest regrowth on temporarily abandoned cropland bring the total area supporting woody vegetation to 5.2 billion hectares, almost 40 percent of the world's land.[3]

The most worrisome finding of FAO's assessment was that tropical trees were being cut much faster than nature or reforestation were replacing them. For tropical regions as a whole, 11.3 million hectares were cleared annually in the early eighties, while only 1.1 million hectares of plantations were established. Thus 10 hectares were being cleared for every 1 planted. In Africa, the ratio was 29 to 1; in Asia, 5

Table 1: The Global Forest Resource Base, Circa 1980

| Region | Closed Forest | Open Woodland | Total Forest | Forest Fallow and Shrubland | Total |
|---|---|---|---|---|---|
| | | | (million hectares) | | |
| Asia (except China) | 332 | 50 | 382 | 107 | 489 |
| Africa | 221 | 499 | 720 | 608 | 1,328 |
| Latin America | 693 | 240 | 933 | 313 | 1,246 |
| North America | 459 | 275 | 734 | — | 734 |
| Europe | 137 | 22 | 159 | — | 159 |
| Soviet Union | 792 | 137 | 929 | — | 929 |
| China | 122 | 15 | 137 | — | 137 |
| Oceania | 72 | 86 | 158 | 2 | 160 |
| World | 2,828 | 1,324 | 4,152 | 1,030 | 5,182 |

Sources: Closed forest and open woodland data from World Resources Institute/International Institute for Environment and Development, *World Resources 1987* (New York: Basic Books, 1987), based on unpublished data from FAO that revised FAO/Economic Commission for Europe, *World Forest Resources 1980* (Rome: 1985), the source of the forest fallow and shrubland data here; China data from China Scientific and Technological Information Research Institute, *China in the Year 2000* (Beijing: Science and Technology Documents Publishers, 1984).

to 1. Even these alarming figures probably underestimate the extent of forest loss in particular regions, since tree planting is often highly concentrated, while cutting is widespread. In tropical Latin America, for example, 77 percent of all industrial and 92 percent of all nonindustrial plantations are concentrated in Brazil. And most of these are in the south, even though most of Brazil's forest clearing takes place in the north.[4]

Moreover, FAO uses a very narrow definition of "deforestation," counting only areas completely cleared of trees. Not included are vast sections severely impoverished through destructive logging, over-

"Satellite imagery shows that deforestation in parts of the Amazon has proceeded much faster than estimates for the entire region suggest."

grazing, fires, or other forms of degradation. Although consistent with FAO's focus on forests as an economic resource, this view ignores transformations that may compromise a forest's ecological integrity. Such disturbances profoundly limit the number and types of species a forest can sustain, as well as forests' role in stabilizing soil and water resources.



Recent data for individual countries also suggest that forest cover trends in some regions are even bleaker than FAO's sobering assessment would indicate. Satellite imagery of five states in Brazil, for example, shows that deforestation in parts of the Amazon has proceeded much faster than estimates for the entire region suggest. Likewise, Landsat data released by the National Remote Sensing Agency of India reveal that India's forest cover declined from 16.9 percent in the early seventies to 14.1 percent in the early eighties, an average loss of 1.3 million hectares per year. The FAO study placed India's forest cover in 1980 at 17.4 percent--approximately 11 million hectares too high—and underestimated the true rate of deforestation almost ninefold. FAO has begun a second tropical forest inventory that will rely more heavily on satellite imagery; thus a more accurate picture of forest cover and deforestation rates should be available within a few years.[5]

Fortunately, reforestation is also proceeding somewhat faster than official estimates suggest. The FAO study estimated that in 1980, plantations covered 11.5 million hectares in tropical countries (excluding China), nearly two-thirds of which produced wood for industrial purposes. Half of these industrial plantations were in tropical Asia, primarily in India and Indonesia; less than one-sixth were in tropical Africa. FAO projected that during the early eighties, industrial plantations would expand at an annual rate of 581,000 hectares, while fuelwood and other nonindustrial plantations would grow by 519,000 hectares annually. (See Table 2.) Estimated planting rates varied greatly, with Brazil topping the list at roughly 449,000 hectares per year. By the end of 1985, plantations were projected to cover some 17 million hectares in the tropics, an area roughly twice the size of Austria.[6]

**Table 2: Establishment of Plantations in the Tropics, 1976–80, With Projections for 1981–85**

| Plantation Type/Region | Annual Area Planted 1976–80 | Annual Area Planted 1981–85 | Total Area by 1985 |
|---|---|---|---|
| | (thousand hectares) | | |
| Industrial | 504 | 581 | 9,968 |
| Tropical America | 209 | 282 | 3,979 |
| Tropical Africa | 53 | 65 | 1,319 |
| Tropical Asia | 242 | 234 | 4,670 |
| Nonindustrial | 419 | 519 | 7,039 |
| Tropical America | 201 | 252 | 3,314 |
| Tropical Africa | 41 | 62 | 1,092 |
| Tropical Asia | 177 | 205 | 2,633 |
| Total | 923 | 1,100 | 17,007 |

Source: U.N. Food and Agriculture Organization, *Tropical Forest R*[illegible], Forestry Paper 30 (Rome: 1982).

The FAO data, however, underestimate reforestation by disregarding spontaneous tree planting by villagers around farm fields, as windbreaks, or along roadways. Indeed, as with most forestry statistics, the FAO numbers ignore "trees outside of forests," even though in many areas these are the primary sources of fuelwood, fodder, and rural construction materials. In Kenya, for instance, the number of trees planted by villagers exceeds the number established in government plantations. And in Rwanda, scattered trees planted by rural people collectively cover some 200,000 hectares, more than the combined area of the country's remaining natural forest and all state and communal plantations.[7]

While encouraging, village tree planting efforts far from compensate for accelerating deforestation in tropical countries. Deforestation is driven by powerful forces—population growth, poverty, landlessness, and consumer demand—that soon overwhelm the capacity of societal and natural systems to respond.

Conversion of forest to cropland is by far the leading direct cause of deforestation in the tropics. Population growth, inequitable land distribution, and the expansion of export agriculture have greatly reduced the area of cropland available for subsistence farming, forcing many peasants to clear virgin forest to grow food. These displaced cultivators often follow traditions of continuous cropping that are ill suited to fragile forest soils. Eventually, the soils become so depleted that peasant colonists must clear more forest to survive.

Indigenous "shifting cultivators," on the other hand, clear new fields every few years, then allow forest regrowth to restore soil fertility before they return to clear and plant crops again many years later. FAO estimates that shifting cultivation is responsible for 70 percent of closed forest clearing in tropical Africa, nearly 50 percent in tropical Asia, and 35 percent in tropical America. But even this once-sustainable practice is being undermined as population pressures force farmers to recultivate land before it has recovered. Once disrupted, shifting cultivation can lead to serious land degradation as repeated croppings so deplete soils that new forest growth cannot take hold. Indonesia alone has more than 16 million hectares of nonproductive land that is incapable of supporting agriculture or forest without major rehabilitation.[8]

In some areas, population pressures have also transformed fuelwood collection into an unsustainable practice. Given a choice, villagers generally gather dead wood and branches for fuel; they only cut live wood if nothing else is available or if they are converting wood to charcoal for urban markets. Fuelwood collection is thus an agent of forest destruction primarily in the arid woodlands of Africa, where population density is high and the natural growth rate of vegetation is low, and around large cities of Asia and Africa, where concentrated demand overtaxes available tree stock. Recent Landsat data show that in less than a decade forest cover within 100 kilometers of India's major cities dropped by 15 percent or more; the area surrounding Delhi lost a staggering 60 percent. (See Table 3.)[9]



An additional agent of forest destruction operates in Latin America: the lure of cattle ranching. Between 1961 and 1978, pasture in Central America expanded 53 percent while forests and woodlands declined 39 percent. Much of this conversion was driven by U.S. demand for cheap beef, although in recent years Central American beef exports have dropped in response to declining U.S. beef consumption, escalating tensions in El Salvador, the U.S. trade embargo against Nicaragua, and pressure from environmental and consumer groups. Similarly, by the late seventies an estimated 1.5 million hectares of pasture had been established in the Brazilian Amazon. In 1979, Brazil eliminated some of the incentives that had spurred clearing for pasture; regrettably, forest clearing continues as a way of establishing claims in Brazil's highly speculative land market.[10]

Industrial countries' appetite for tropical hardwoods also has encouraged many developing-country governments to "mine" their forests

**Table 3: India: Changes in Closed Forest Cover Around Major Cities, 1972–75 to 1980–82**

| City | 1972–75 | 1980–82 | Change |
|---|---|---|---|
| | (square kilometers) | | (percent) |
| Bangalore | 3,853 | 2,762 | −28 |
| Bombay | 5,649 | 3,672 | −35 |
| Calcutta | 55 | 41 | −25 |
| Coimbatore | 5,525 | 4,700 | −15 |
| Delhi | 254 | 101 | −60 |
| Hyderabad | 40 | 26 | −35 |
| Jaipur | 1,534 | 786 | −49 |
| Madras | 918 | 568 | −38 |
| Nagpur | 3,116 | 2,051 | −34 |

Source: B. Bowonder et al., "Deforestation Around Urban Centres in India," *Environmental Conservation*, Vol. 14, No. 1, 1987.

"Unsustainable logging in Côte d'Ivoire has contributed to a halving of the nation's forested area over the last two decades."

to earn vital foreign exchange. For example, Malaysia—currently the leading tropical log exporter—derives all of its export logs from the states of Sabah and Sarawak. The rate of timber harvesting in Sabah is four times the rate of natural regeneration. Similarly, unsustainable logging in Côte d'Ivoire has contributed to a halving of the nation's forested area over the last two decades. If present loss rates continue, the country's forest will be completely gone in 16 years.[11]



Moreover, as loggers selectively cut commercially valuable tree species—which typically account for between 2 and 10 percent by volume of any given hectare—they often destroy between 30 and 60 percent of unwanted trees as well. Thus, while logging can in theory be practiced sustainably, more often it severely degrades forestland. FAO estimates that about 4.4 million hectares of forest are "logged over" each year, in addition to the 11.3 million hectares that are completely cleared. To date, roughly two-thirds of the logging—and the damage—has occurred in Southeast Asia, although logging is likely to increase in Latin America, and eventually Africa, as Asian forests become depleted.[12]

Logging also promotes deforestation indirectly through the construction of roads that allow slash-and-burn agriculturalists to penetrate deeper into virgin forest. The building of a new road or even the improvement of an existing one is generally sufficient to encourage spontaneous migration by land-hungry peasants. This is particularly true in mainland Southeast Asia, where the expansion and consolidation of export agriculture in the lowlands has displaced marginal farmers and sharecroppers.[13]

In some countries, most notably Brazil and Indonesia, governments and international aid agencies have actively encouraged colonization of outlying forested areas. Under its massive transmigration scheme, for example, the Indonesian government has ferried more than 4 million peasant farmers from the crowded islands of Java and Bali to the less populated, heavily forested outer islands of the archipelago. The government justifies the program as a means of relieving population pressure and increasing domestic food production. Critics charge that it is merely a way to defuse political unrest on Java while consolidating Javanese control over the ethnically diverse outer islands.[14]



Like most resettlement projects, the Indonesian transmigration scheme sacrifices tropical forest while offering little hope of providing sustainable livelihoods for incoming migrants. Given poor forest soils, agricultural yields on cleared plots have been disappointingly low; half of all resettled farmers still live on poverty incomes below $360 a year. Recently, the government has drastically slashed plans for future settlement in response to declining oil revenues and international pressure from environmental and tribal rights groups. Future investment is expected to concentrate on enhancing the economic and ecological viability of existing resettlement sites.[15]

Increasingly, the World Bank and other international lending agencies have been criticized for their support of transmigration and other large-scale projects that destroy tropical forests. By funding colonization in Indonesia, road building in Brazil, and large dams in India and elsewhere, development aid agencies have abetted the devastation of vast tracks of forest. Although most projects involve trade-offs, and some forest destruction may be unavoidable in certain circumstances, critics are most concerned with projects where environmental side-effects outweigh intended benefits or where the benefits are unsustainable. In response, the World Bank has recently established a full-fledged department charged with reviewing the environmental impacts of all prospective projects and has added environmental units to each of its regional divisions. A new U.S. law requires the U.S. Executive Directors of all the other multilateral development banks "to vigorously promote" comparable review processes as well as increased funding for environmentally beneficial projects.[16]

Nothing in prospect suggests that forest cover in the Third World will stabilize anytime soon. The forces behind deforestation remain strong, and planting efforts are woefully inadequate to reverse the loss of tree cover. By contrast, pressures on temperate forests have waned substantially following several centuries of clearing for agriculture. Forest cover in most European countries is now fairly stable; in some, it has even been increasing as marginal agricultural land reverts to woodland and as conscious efforts are made to plant trees. Since the early sixties, for example, government and private plantings in the United Kingdom have increased net forest cover an average of 30,000–40,000 hectares per year. In France, forest area has risen substantially from its historic low of 14 percent two centuries ago; about a quarter of the country is now forested.[17]

Unfortunately, chemical stresses from air pollution and acid rain today place a considerable share of European forests at risk. Trees covering some 31 million hectares in central and northern Europe, more than a fifth of the forested area, are showing signs of damage linked to air pollutants. Scientists do not know how extensive the damage will become, but it could substantially offset recent gains made in expanding the continent's forests.[18]

As in Europe, forest cover in the contiguous United States has been comparatively stable during most of this century, following the loss of 136 million hectares between 1630 and 1920. During the last two decades, however, forest area has declined as expanding grain export markets encouraged conversion of forest to cropland and as urban and industrial development encroached on woodlands. In 1982, forests covered 233 million hectares of the contiguous states—the smallest area in the nation's history, and a 10-percent drop since 1963.[19]

## The Fuelwood Challenge

Energy planners in developing countries face a markedly different set of challenges over the coming decades than their counterparts in industrial countries. Much of the Third World remains tightly wedded to wood as a primary energy source, either in its raw form or after conversion to charcoal. As wood supplies in the countryside and around cities continue to dwindle, growing numbers face a deepening energy crisis. Even after more than a decade of increasing recognition of the problem, only halting progress has been made toward satisfying future fuelwood demands.

More than two-thirds of all Third World people rely on wood for cooking and heating. Rural dwellers depend on wood almost exclusively, even in oil-rich Nigeria. In many countries—including most of Africa—wood not only dominates household energy use, it provides more than 70 percent of energy used for all purposes. (See Table 4.)[20]



**Table 4: Share of Total Energy Use Provided by Wood, Selected Countries, Early Eighties**

| Country | Wood Share of Total Energy Use |
|---|---|
| | (percent) |
| Africa | |
| Burkina Faso | 96 |
| Kenya | 71 |
| Malawi | 93 |
| Nigeria | 82 |
| Sudan | 74 |
| Tanzania | 92 |
| Asia | |
| China | >25[1] |
| India | 33 |
| Indonesia | 50 |
| Nepal | 94 |
| Latin America | |
| Brazil | 20 |
| Costa Rica | 33 |
| Nicaragua | 50 |
| Paraguay | 64 |

[1]Includes agricultural wastes and dung in addition to wood and charcoal.

Source: Worldwatch Institute, based on various sources.

Unfortunately, data characterizing the fuelwood gap are as out of date and approximate as those on tropical forest trends. According to FAO, in 1980 nearly 1.2 billion people in developing countries were meeting their fuelwood needs only by cutting wood faster than it was being replaced. Nearly 100 million people—half of them in tropical Africa—could not meet their minimum needs even by overcutting the woodlands around them. FAO projected that by the year 2000, the number of people lacking wood or overcutting would double, reaching nearly 2.4 billion, more than half the projected developing-world population. (See Table 5.)[21]



The human and ecological costs of wood scarcity already are high. In rural parts of the Himalayas and the African Sahel, women and children spend between 100 and 300 days a year gathering fuelwood. Boiling water becomes an unaffordable luxury, and quick-cooking tubers and cereals replace more nutritious but slower-cooking foods, such as beans. Where fuelwood is critically scarce, people often have

**Table 5: Populations Whose Fuelwood Supplies Cannot Be Sustained, 1980, With Projections for 2000**

| Region | 1980 Acute Scarcity[1] | 1980 Deficit[2] | 1980 Total | 2000 Acute Scarcity or Deficit |
|---|---|---|---|---|
| | (millions of people) | | | |
| Tropical Africa | 49 | 200 | 249 | 622 |
| Tropical Asia[3] | 29 | 710 | 739 | 1,434 |
| Tropical America | 18 | 143 | 161 | 342 |
| Total | 96 | 1,053 | 1,149 | 2,398 |

[1]Fuelwood consumption below that required to meet minimum needs.
[2]Minimum fuelwood needs are met, but only by overcutting and depleting wood resources.
[3]Does not include China.

Source: U.N. Food and Agriculture Organization, *Fuelwood Supplies in the Developing Countries*, Forestry Paper 42 (Rome: 1983).

no choice but to divert dried dung and crop residues from fields to cookstoves, a practice that can diminish soil fertility and depress crop yields. In Nepal, for example, this diversion reduces grain yields an estimated 15 percent.[22]



In urban areas where fuelwood is bought and sold, the impact of scarcity is no less severe. Working-class families throughout the Third World typically spend 20–40 percent of their meager incomes to buy wood or charcoal. Lacking the energy safety net of crop waste or dung, the urban poor must accept reduced living standards in response to rising fuelwood prices.[23]

Unfortunately, rapid urbanization in the Third World will only magnify the ecological consequences of increasing fuel scarcity. City dwellers tend to rely on charcoal rather than wood because its light weight makes it more economical to transport from the countryside. But when wood is converted to charcoal in traditional earthen pits, more than half the primary wood energy is lost. This means that every villager who moves to a city and switches from wood to charcoal equals, in energy terms, two people. Even though urban areas have traditionally been less dependent on fuelwood, urbanization could soon make cities pivotal to national fuelwood strategies. Indeed, the World Bank estimates that by 2000, the urban areas of West Africa will account for 50–70 percent of the region's total fuelwood consumption.[24]

Experts generally agree that a successful strategy to meet the fuelwood needs of the Third World will involve both increasing wood supplies and reducing demand. But no single course of action will work in every case. Nor are all useful responses solely related to energy or forestry. Indeed, many policies that could significantly reduce demand attack the broader economic, agricultural, and social conditions that underlie fuelwood shortages. Intensifying agricultural production or redistributing land, for example, can reduce the need to clear additional wooded areas for cropping, thereby preserving natural vegetation as a source of fuelwood. Similarly, programs designed to control population growth can greatly reduce future wood needs. If birth rates today in Africa were no higher than those in South Asia, "Every villager who moves to a city and switches from wood to charcoal equals, in energy terms, two people."

Africa's demand for fuelwood 40 years from now would be as much as 30 percent lower.[25]



Likewise, measures to increase wood supply do not necessarily involve planting trees. There is considerable potential in developing countries to make better use of existing wood resources. Work carried out in Sudan has demonstrated that up to 50 cubic meters of fuelwood can be recovered from each hectare of land being cleared for agriculture. If cut rather than burned in place, this wood could supply a family of seven with fuel for almost a decade. Uganda has realized similar savings by converting logging wastes into charcoal for urban consumption. As a result, charcoal production has risen from 200 tons per year to 63,700 tons.[26]

Yet even with marked reductions in demand and better use of wood currently wasted, developing countries will still need to increase fuelwood supplies by planting trees. According to a rough reckoning by the World Bank, developing nations (excluding China) would have to plant the equivalent of 55 million hectares of high-yielding fuelwood plantations between 1980 and 2000 to bring supply into balance with demand. This planting target assumes that 25 percent of demand could be met through fuel substitution and the use of more-efficient kilns and cookstoves. If the needed number of trees were planted less intensively on farms, around houses, and in woodlots—the more likely scenario—planting efforts would involve an area at least four times as large. Actual establishment of fuel plantations has averaged about 519,000 hectares annually, less than a fifth of what is needed.[27]

Admittedly such calculations are crude: Data on tree planting and fuelwood consumption are notoriously poor and assumptions about the potential of conservation and substitution are at best informed guesses. Moreover, the World Bank projection does not take into account crop wastes or wood available from trees outside of forests or spontaneously planted by villagers—omissions that may serve to underestimate the biomass available for future fuel. But the underlying trend is nonetheless clear: Accelerated tree planting is needed to avert a deepening fuelwood crisis.

More than a decade of experience with so-called communal and farm forestry projects has shown that inspiring widespread planting of trees is no easy task. The international development community rightly recognized during the seventies that plantations established and maintained by government foresters were too expensive and labor-intensive for the task at hand; Third World villagers themselves formed the only labor force large enough to plant trees on the vast areas needed. In many cases, however, rural people were reluctant to participate in communal planting because they had no idea how the resulting benefits would be shared. Often their needs and ideas were not solicited, nor were they involved in the selection of tree species to be planted. Perhaps the greatest lesson of the first generation of fuelwood projects was that villagers rarely were motivated to plant trees exclusively for fuelwood.

To outside observers, it seems irrational for people faced with an energy crisis to be reluctant to plant trees for fuel. But for most rural dwellers in the Third World, fruit, poles, fodder, and shade are higher priorities. They know that wood, in the form of trimmings and dead branches, will be a secondary benefit of planting for these other purposes. Moreover, people do not always perceive the national "fuelwood gap" that so concerns energy planners. They may be cutting wood over and above a sustainable level, yet still not be experiencing an unacceptable shortage. And in rural areas where fuelwood is not part of the cash economy, the cost of increasing scarcity is measured in women's time, something that may have little value to male decision makers.

The key to mobilizing villagers in the battle against wood scarcity is to promote the growing of trees that meet their immediate needs while also increasing the woody biomass available for fuel. Particularly promising is the potential of agroforestry—the combined production of crops and trees—to raise crop yields while providing fuelwood and other useful products. Nitrogen-fixing trees planted in shelterbelts or interspersed with crops, for example, can enhance soil fertility, increase soil moisture, and reduce erosion.[28]

Agroforestry programs offer a number of advantages over more traditional approaches to addressing the fuelwood crisis. They typically

"Particularly promising is the potential of agroforestry to raise crop yields while providing fuelwood and other useful products."



cost only 10–20 percent as much as government-established fuelwood plantations. Since trees are dispersed on farms rather than concentrated in plantations, agroforestry makes trees more accessible and spreads their benefits more widely. Although yields per hectare may be higher in plantations, agroforestry often results in greater wood production per planted tree. Through special pruning techniques, a single tree can yield 5–10 times the wood volume that a plantation tree would yield upon felling. Even without management, farm trees generally yield more biomass because they have less competition and benefit from the better soils allocated to agriculture. And in contrast to communal woodlot projects, agroforestry does not pose problems with shared work loads, division of benefits, or the displacement of other productive uses of common land, such as grazing.[29]

Of course, agroforestry does not address the fuelwood needs of the millions of rural people who do not own land. Traditionally, they have had to collect wood from common lands or steal it from forest reserves. Providing fuel for the landless may well be the greatest energy challenge facing Third World governments today.

In India, the government of West Bengal addressed this problem by allocating more than 5,000 hectares of denuded forestland to landless families for cash-crop tree farming. Families were not ceded title to the land, but they were granted ownership of the trees. To encourage participation, the Forest Department supplied free seedlings, fertilizer, technical assistance, and insecticide, and it offered small cash incentives based on the number of trees surviving after three years. The families harvested the wood for sale after five years, and with the proceeds bought small parcels of land suitable for farming. While the trees matured, villagers collected twigs and branches for fuel. Where a strong commercial market for wood exists and sufficient degraded forestland is available, such a strategy can bring marginal land into productive use while providing the landless poor with both fuelwood and added income.[30]

Meeting the fuelwood demands of the Third World's burgeoning cities also presents special challenges. Historically, because cutting fees have been low and forest reserves difficult to police, firewood collectors have been able to "mine" the biological capital of the countryside, providing urban markets with fuelwood at prices far below replacement cost. This merely transfers the cost of fuelwood forward in time—to current users' children, who will face an ecologically depleted countryside.

Theoretically, raising the price of fuelwood should encourage substitution and make commercial production of wood more economical. But it is exceedingly difficult to protect natural forests from pilferage while administering an organized fuelwood market that controls price through extraction and distribution fees. Such schemes also tend to have devastating effects on the rural poor, since strict policing of forest reserves deprives them of a major source of income: the sale of scavenged fuelwood. Higher fuel prices in the city, in turn, further burden the already strained budgets of the urban poor.

Rather than trying to develop government-controlled fuelwood markets, some countries are attempting to enlist the help of rural people in managing the existing forest resources. The government of Niger, for example, is considering placing some forests near urban areas under the control of local villagers. In return for managing the resource, the villagers would reap the financial benefits of cutting fees paid by wood collectors licensed to collect fuel from their area. For this approach to work, villagers must be granted tree or land tenure, much as they were in West Bengal, to assure them an adequate return on the resources that they are managing. But a move toward privatization allows government forest services to use scarce resources for developing community management skills rather than policing forests against would-be fuel scavengers.[31]

With city dwellers consuming a growing share of fuelwood supplies, increasing the efficiency of urban wood-burning is also crucial. After two decades of unrealistic hopes and false starts, energy planners now have a much better idea of the role that improved cookstoves can play in national fuelwood strategies. Stove programs will never solve the fuelwood crisis; population growth would soon outstrip even the most ambitious dissemination program. But improved stoves can enhance the health and economic standing of individual households

"Local artisans in Kenya now make an improved version of the traditional charcoal jiko that can halve fuel use."

while collectively relieving pressures on natural woodlands as tree planting programs take hold.



Especially promising are the chances for improving the portable metal cookstoves frequently used in Third World cities. In urban areas where fuel must be bought, rising wood and charcoal prices provide a strong incentive to invest in efficiency. Also, because urban stoves are manufactured rather than constructed in place, design improvements are relatively easy to introduce, standardize, and disseminate. In Kenya, for example, local artisans now make an improved version of the traditional charcoal jiko that can halve fuel use. For the average Nairobi family spending 170 shillings (about $8.25) a month on charcoal, the stove pays for itself in just two months.[32]

Strategies for increasing fuel efficiency in rural areas, however, are considerably more difficult. Because wood is gathered rather than purchased, no economic advantage exists to boosting wood-burning efficiency. Yet women, who spend much time collecting wood, have an incentive to construct improved stoves if they can do so from free, locally available materials. An effective design will also accommodate cultural factors such as rural people's need for heat and light, the size of cooking pots, and the food to be cooked.

A particularly successful program in Burkina Faso promotes an upgraded version of the traditional three-stone cookstove, surrounded by a cylindrical shield made of mud, dung, and chaff. The new model cuts wood use by 35–70 percent, takes only a half-day to make, and costs virtually nothing. By April 1986, more than 83,500 of these improved stoves were in use.[33]

## Supplying Industrial Wood

Next to the foreboding picture for fuelwood, prospects for meeting the world's industrial wood needs appear relatively bright. Trees used to make plywood, panels, furniture, paper, and other industrial products command prices in an international market that encourage planting and management for these purposes. Yet the persistence of unsustainable and environmentally destructive logging in tropical forests and the growing drain that rising wood product imports place on Third World economies call for new approaches to supplying industrial forest products.



In 1985, world production of industrial roundwood—the logs, pulp, and other raw materials used to manufacture wood products—totaled 1.5 billion cubic meters. Three-quarters of that came from 10 countries, and half came from just three: the United States, the Soviet Union, and Canada. (See Table 6.) Recent projections suggest that annual worldwide demand for industrial wood will rise to between 1.7 billion and 2 billion cubic meters by the year 2000. With increases

**Table 6: World Production of Industrial Roundwood, 1985**

| Country | Volume | Share of Total |
|---|---|---|
| | (million cubic meters) | (percent) |
| United States | 347 | 23 |
| Soviet Union | 275 | 18 |
| Canada | 165 | 11 |
| China/Taiwan | 93 | 6 |
| Brazil | 58 | 4 |
| Sweden | 49 | 3 |
| Finland | 39 | 3 |
| Japan | 33 | 2 |
| Malaysia | 32 | 2 |
| France | 29 | 2 |
| All others | 383 | 26 |
| World Total | 1,503 | 100 |

Source: U.N. Food and Agriculture Organization, *Yearbook of Forest Products 1985* (Rome: 1987).

"Over the last decade, annual consumption of industrial forest products in developing countries doubled."

in sustainable wood production expected to exceed this higher need, no gap between global supply and demand for industrial wood appears likely over the near term.[34]



Even now, however, certain types of wood—most notably, tropical hardwoods—are not being supplied on a sustainable basis. A natural forest's climax species, which tend to be the most valuable, typically cannot regenerate fully within the normal 25–35 year logging cycling common in many tropical countries. Consequently, in the absence of intensive management efforts, the quality and volume of merchantable species in exploited forests diminish. Burgeoning demand in Europe, Japan, and the United States led to a doubling of annual tropical log extraction between 1960 and 1980. Japan's imports alone quadrupled. Timber companies met this demand by continually moving into untouched territories, degrading ever larger areas of virgin forest.[35]

Tropical timber in many areas is thus being mined, much like gold, oil, and other nonrenewable resources. Over time, such depletion has serious economic consequences. Nigeria was once among the world's largest tropical log exporters, but hardwood log exports declined from 773,000 cubic meters in 1964 to a mere 60,000 cubic meters in recent years, mainly as a result of overexploitation of its forests. (See Figure 1.) The nation earned only $6 million from its exports of all forest products in 1985 and spent $160 million that year on forest product imports. Similarly, in Ghana the volume of forest product exports dropped by two-thirds between 1974 and 1985. Although some 33 developing countries are currently net exporters of wood, that figure may drop to around 20 in little more than a decade.[36]

Developing-country economies also face rising demands for industrial wood products. Plywood, paper, newsprint, and other processed wood materials are essential to economic and social development. Over the last decade, annual consumption of industrial forest products in developing countries doubled, to 240 million cubic meters. With demand for sawnwood projected to rise 70 percent by the year 2000, for panels 180 percent, and for paper and paperboard 90 percent, Third World industrial wood demand is likely to roughly double

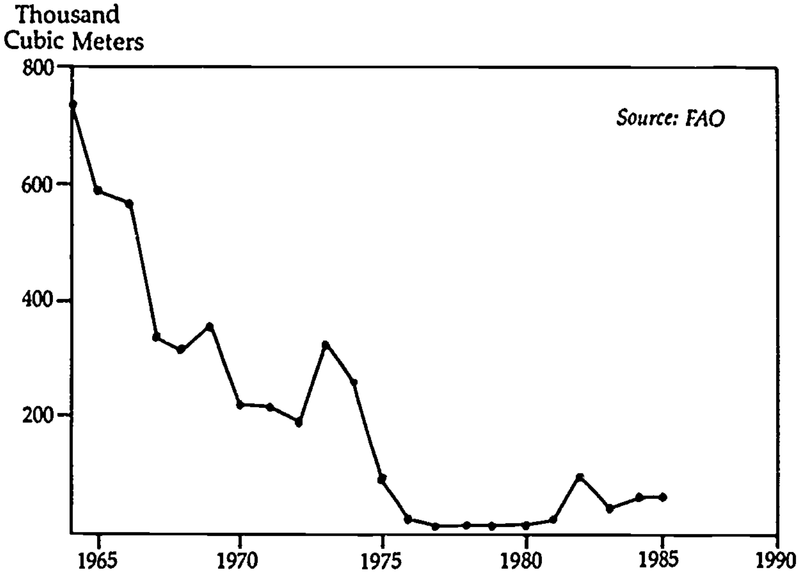


**Figure 1: Hardwood Sawlog and Veneer Log Exports, Nigeria, 1964–85**

again within 15 years. Lacking sufficient wood-processing capabilities, the vast majority of developing countries—even those with substantial forest resources—import these commodities at great cost. Per capita use of paper and other vital forest products will thus remain constrained by an inability to afford increased imports, especially in countries saddled with debt.[37]

A combined strategy of establishing tree plantations, improving forest management practices, and getting more value out of existing wood resources could curb the unsustainable logging of tropical forests and help developing countries meet growing demands for wood products. Each of these measures holds much potential, though their relative merits vary greatly among countries and regions.

Favorable growing conditions give southern hemisphere nations a decided advantage over most industrial countries in the economics of wood production. Plantations in the South can produce 10-20 cubic meters of wood per hectare per year, considerably more than plantations in most northern temperate regions and 10-20 times the typical productivity of natural forests worldwide. Increasing the area of plantations can thus ease pressures to log large areas of natural forest. Assuming, for example, an average annual yield of 15 cubic meters per hectare, plantations covering 33 million hectares—equal to just 16 percent of the total area of tropical forest that has been logged over—could meet the Third World's projected demand for industrial wood in the year 2000.[38]



As of 1985, industrial plantations worldwide covered nearly 92 million hectares. (See Table 7.) The Soviet Union and China account for more than 40 percent of that total, although data on the area of plantations successfully established in both countries and the relative distribution of plantations for land reclamation, wood, and other purposes are somewhat unclear. The United States follows, having established roughly 12 million hectares of industrial plantations—mostly in the Southeast.[39]

Among developing countries, Brazil, Chile, Zambia, and Zimbabwe have reaped substantial benefits from industrial wood plantations. In Chile, some 327,000 hectares of pine had been established by 1974, largely through the government-owned National Forestry Corporation. That year, the new Pinochet government boosted private incentives for planting by decreeing that the National Forestry Corporation would reimburse private parties for three-quarters of the cost of establishing and maintaining plantations, provided a sufficient share of seedlings were shown to survive. The new law also required that areas be replanted after harvesting, and it exempted all forestlands from expropriation, thereby securing private rights to plantations.[40]

Following the law's enactment, the annual reforestation rate in Chile roughly doubled. By 1985, pine plantations covered 1.1 million hectares, a large area given that Chile's natural forests cover only some 20 million hectares. (See Figure 2.) Having invested substantially in

Table 7: Estimated Industrial Forest Plantations Worldwide, Circa 1985[1]



| Country/Region | Area (thousand hectares) |
|---|---|
| Soviet Union | 21,900 |
| China[2] | 17,500 |
| United States[3] | 12,107 |
| Japan | 9,584 |
| Brazil | 3,500 |
| India | 1,960 |
| Indonesia | 1,800 |
| Canada[4] | 1,528 |
| Chile | 1,227 |
| South Africa | 1,115 |
| New Zealand | 1,089 |
| Australia | 833 |
| Argentina | 550 |
| South Korea | 400 |
| Nigeria | 270 |
| Western Europe[5] | 13,000 |
| Other | 3,335 |
| Total | 91,703 |

[1]Does not include areas that naturally regenerate after logging, a process that occurs more readily in temperate countries than in tropical ones.
[2]Midpoint of estimated range of 15,000 to 20,000.
[3]Includes only industrial plantations in 12 southern states and in the Pacific Northwest, accounting for at least 90 percent of planting for timber.
[4]Includes only plantations established since 1975.
[5]Plantations as of 1975.

Source: Worldwatch Institute, based on various sources.

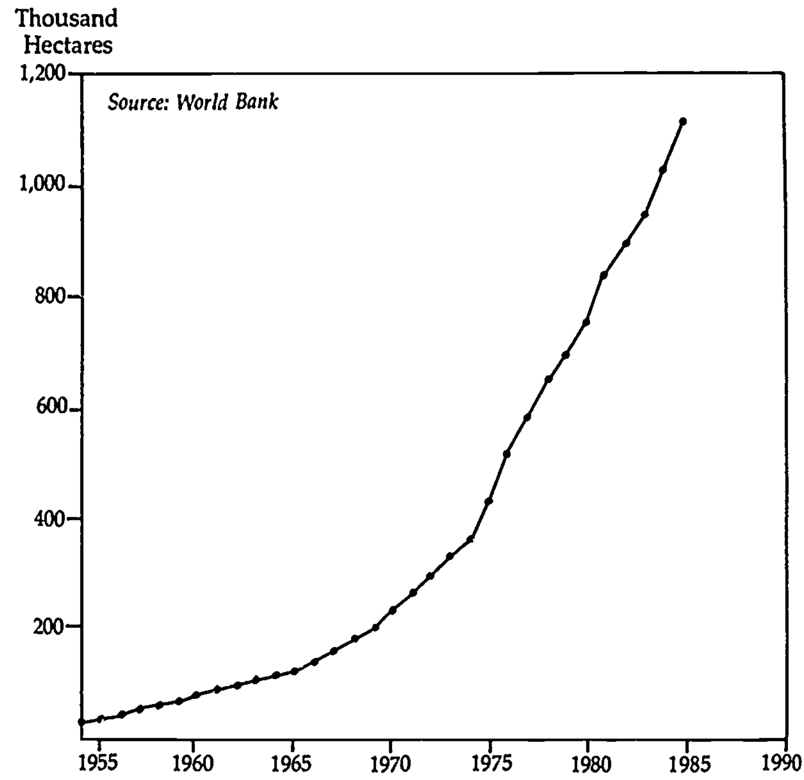


**Figure 2: Cumulative Area Planted in Pine, Chile, 1954–85**

sawmills and in pulp and paper mills to process its growing volumes of wood, Chile is now self-sufficient in forest products. Exports have expanded markedly, reaching over $400 million in 1986—nearly 10 percent of the nation's export earnings that year. Although subsidies totaling some $50 million since 1974 account for much of the effort's success, this amount is small compared with the long-term benefits the plantations will bring to Chile's economy.[41]

Brazil offers another success story in Latin America, having established more than 5 million hectares of industrial plantations, mostly of eucalyptus and pine. The World Bank estimates that when managed on a sustained yield basis, these plantations will produce as much industrial wood as in all the Scandinavian countries combined. Once an importer of pulp and paper, Brazil earned $540 million from its pulp and paper exports in 1985. As in Chile, Brazil's success stems largely from financial incentives offered to encourage private planting.[42]



In Africa, both Zambia and Zimbabwe are reaping substantial gains from industrial reforestation, even though their total plantation areas are comparatively small. Zambia's 45,000 hectares of plantations—mostly pine and eucalyptus—are expected to meet the nation's industrial timber needs through the end of the century. Residues from sawmilling are given free to local families for conversion to charcoal, helping meet rural energy needs. Zimbabwe, too, has built a successful forest industry around a commercial timber base of 100,000 hectares of plantations. Hilly terrain, soils ill suited for agriculture, and plentiful rainfall made eastern Zimbabwe the focus of planting efforts. Around the country, several dozen sawmills, along with mills for making newsprint, particle board, kraft and tissue paper, and other products, supply virtually all domestic needs. For nearly a decade, an expanding surplus has been exported to neighboring countries.[43]

Although clearly holding the potential to increase Third World wood self-sufficiency, plantations are not without problems. When trees on them are harvested, they generally take along a large stock of nutrients, requiring increasing applications of fertilizer to maintain the site's productivity. Moreover, like many monoculture cropping systems, plantations are particularly susceptible to attack by insects and disease. In Southeast Asia, the jumping plant louse is currently devastating thousands of hectares of leucaena, long considered a "wonder tree" because of its high yields and ability to fix nitrogen. The Philippines alone stands to lose 50,000 hectares if the infestation is not controlled.[44]

"Regrettably, at least 15 percent of plantations in the tropics were established at the expense of natural forest."

Despite pest problems, the high productivity of plantations raises the temptation to substitute them for lower-yielding stands of natural forest. But the conversion of even logged-over forest to plantation can have severe consequences for indigenous people, wildlife, and overall ecosystem stability. Regrettably, at least 15 percent of all plantations in the tropics—and a third of those in tropical Asia—were established at the expense of natural forest. Many tropical nations harbor large areas of abandoned and degraded land near population and transportation centers that could support plantations; in most cases, natural forest need not be converted to monoculture stands in order to boost industrial wood production. Brazil alone, for example, has some 8 million hectares of abandoned pasture land, at least a portion of which could support plantations of hearty, fast-growing trees.[45]



Better management of natural forests also holds potential for increasing sustainable production of industrial wood. Besides increasing overall yields, it can help renew and sustain the output of valuable tropical hardwoods depleted from logging. A primary objective of natural forest management has been to enhance the regeneration of valuable species by creating an environment conducive to their growth. Measures have included, for example, poisoning undesirable and competing trees, cutting climbers, and opening the canopy to promote the growth of marketable species maturing in the understory. More intensive management can also include "enrichment," whereby natural regeneration is augmented by planting seeds or seedlings of desirable species. Though a managed forest is clearly altered from its original state, it continues to offer many of the ecological and social values that a monoculture plantation cannot.[46]

Most management schemes result in annual yields between a fifth and a third as much as from plantations. Securing an equivalent volume of wood from natural forests thus requires managing a proportionately larger area. Still, assuming an average annual yield of 3 cubic meters per hectare, the management of 165 million hectares—roughly three-fourths the total area of logged-over forest—could meet the Third World's projected demand for industrial wood in the year 2000.

To date, tropical forest management has a rather sparse track record. Less than 5 percent of the tropical forest resource base is being managed at all, and three-quarters of that area is in India. Indeed, since 1960 the area of managed tropical forest has actually decreased as population pressure, a shortage of technical expertise, and other resource constraints have led to the abandonment of many management systems originally implemented by the British in colonial Africa. Even rudimentary felling regulations are often ignored. A survey of logging companies in Indonesia's East Kalimantan region showed, for example, that not one company left standing the number of select trees necessary to replenish the logged-over forest with desirable species, even though their logging contracts required them to do so.[48]

Successful, commercial-scale operations in Indonesia, Malaysia, and the Philippines as well as pilot projects in Brazil, Côte d'Ivoire, and Peru attest to natural forest management's technical feasibility. Indeed, one project in Côte d'Ivoire doubled sustainable production over that of an untouched stand. Although many countries face a serious shortage of trained personnel and material resources for tropical silviculture, this could be overcome. Viable management schemes exist; what is missing is the political will, not the way.[49]

Long maligned as uneconomical compared with industrial plantations, natural forest management schemes have also emerged from recent assessments as quite favorable economically—especially in the highly prized dipterocarp forests of Southeast Asia. For example, in an analysis of a half-dozen wood production alternatives for Indonesia, forest economist Roger Sedjo found that the economic returns from improved management of the natural forest—involving essentially a more thorough harvest of merchantable trees, a longer harvest cycle, and natural or assisted regeneration—exceeded those from several plantation schemes. This proved true even excluding the additional environmental services provided by the natural forest.[50]

Moreover, comparative returns from different wood-producing schemes can vary greatly with the choice of discount rate, an economic tool used to account for the time value of money. A high rate

"Indonesia and Peninsular Malaysia banned log exports in 1985, and the Philippines followed suit in 1986."



biases analyses toward high-yielding plantations on short rotations, while low rates favor the management of natural forests on longer harvest schedules. This value-laden and fairly arbitrary choice greatly shapes land-use decisions. Economist A.J. Leslie argues forcefully that out of concern for future generations, lower-than-typical discount rates should apply to decisions involving natural forests, and concludes that "natural management of the tropical mixed forest, wherever it is ecologically feasible, is also, on its own merits, economically preferable."[51]

Developing nations can also protect their forests by getting more financial mileage out of the resource base that remains. The higher the revenues generated per unit of forest area, the less area needs to be exploited to generate a given amount of foreign exchange. By encouraging local processing, for example, tropical countries can capture the value added through manufacturing, rather than forfeit it to an intermediate processor, such as Japan. In 1984, semimanufactured products, such as plywood and veneer sheets, commanded three times the price of raw logs on the world market.[52]

In recent years, many long-time exporters have taken steps to limit their shipments of raw logs in order to encourage more domestic processing, to supply expanding domestic markets, and to promote the export of higher-valued products. Indonesia and Peninsular Malaysia banned log exports in 1985, and the Philippines followed suit in 1986. Unfortunately, many industrial countries impose high tariffs on processed wood products to protect their own processing industries. This has forced developing-country governments to offer large incentives to encourage domestic investment in sawmills and other processing facilities. Ghana, for example, banned log exports, reduced export taxes on wood products, and offered substantial tax concessions. As a result, 95 sawmills and dozens of other wood-processing facilities sprung up.[53]

Similar incentives have been adopted by Indonesia, the Philippines, and other major tropical wood exporters. This artificial investment environment allows wood-processing facilities to operate very inefficiently and still turn a profit. Yet inefficiency absorbs a good portion of the financial benefit that would normally accompany processing, since excess logs used in inefficient processing plants could have been taxed and exported. Economist Robert Repetto estimates, for example, that unless efficiencies improve, domestic processing will in effect "cost" the Indonesian economy approximately $400 million in 1988.[54] Thus efforts to boost revenues from wood-product exports have in some cases backfired.

Tropical nations clearly have a comparative advantage in processed forest products that they could benefit from realizing. This may only happen, however, if industrial countries reduce their import taxes so that products from developing nations can compete successfully in world markets without excessive subsidies. With a combination of more modest incentives and freer trade, local processing facilities would be forced toward greater efficiency. Governments in turn would capture a larger share of manufacture-added value at a smaller cost in forgone revenues.[55]

Governments in the tropics can also enhance the value of their forests by developing markets for lesser-known tree species. In Southeast Asia, commercial loggers harvest fewer than 100 tree species, with exports consisting of only two dozen or so. By exploiting more species on a given plot of land, countries can limit the area of forest degraded by logging. A few nations have taken steps in this direction in recent years. By 1981, previously unexploited hardwood species accounted for 12 percent of the logs going to Peninsular Malaysia's sawmills and 27 percent of those manufactured into plywood and veneer. Cameroon, Colombia, Indonesia, and the Philippines have also had success marketing secondary species.[56]

Governments can exert some control over the variety of species extracted by structuring revenue systems to discourage "creaming" and logging waste. At present, most charge for timber based on the volume a licensee removes, not the volume of merchantable timber available in the plot. Concessionaires thus take only the most valuable species, and often destroy low-value stems with impunity. By imposing charges that vary with the value of the species, however, the Malaysian state of Sarawak encourages more complete harvesting.

The government also charges per tree removed rather than per cubic meter, further discouraging waste. As a result, logging damage in Sarawak forests is only half that of forests in nearby Sabah and Indonesia.[57]



Sustainably meeting industrial wood needs will require increased investments in plantation establishment, better natural forest management, more efficient processing, freer trade, and improved marketing of wood resources. Given the differing economic and ecological conditions under which forest industries are operating in the Third World, the appropriate mix of these strategies will vary. Yet a rough assessment by an international task force of forest experts suggested a target of establishing some 10 million hectares of plantations over a five-year period. This represents the sum of recommended planting programs for 28 individual countries; for some, the team recommended a continuation of current planting rates, while for others a substantial increase was suggested. Given the successes of a number of countries in establishing industrial plantations, this target appears reachable, but is more likely to require a decade rather than five years.[58]

## Stabilizing Soil and Water Resources

"What do the forests bear? Soil, water, and pure air." So goes a slogan of India's Chipko movement, a nonviolent resistance campaign begun in the early seventies to save trees in the Himalayas. The motto reflects a growing awareness of the role forests play in vital ecological functions: stabilizing soils, conserving nutrients, and moderating water supplies. Unfortunately, deforestation and poor land use practices in many parts of the Third World are undermining these support services at a rapid rate.[59]

Just how much ecological disruption forest clearing causes depends on a number of factors, including topography, rainfall patterns, soil characteristics, geologic conditions, and how the land is used and treated following clearing. In general, forests help anchor soils; thus the loss of tree cover—especially from steeply sloping hillsides—can lead to large losses of topsoil. Besides diminishing upland productivity, such erosion transfers sediment to river channels, which aggravates local flooding and can contribute to the premature silting of reservoirs downstream.[60]

The effects of forest clearing on water supplies seem much more variable and uncertain. In most cases, removing trees increases an area's available water supply, since the amount of water lost to the atmosphere through evapotranspiration decreases. But if overgrazing or poor crop production practices follow forest clearing, soils can compact and lose some of their ability to absorb rainwater. In such cases, more water tends to run over the land rather than soaking into the subsurface, where it can be stored and released more gradually. In West Africa, for example, runoff rates recorded from some cultivated and bare soils exceeded those from forest twentyfold. Depending on the intensity and duration of rainfall, the loss of soil infiltration capacity can also increase flooding.[61]

Perhaps nowhere are the destructive effects of flooding and siltation more evident than in South Asia, especially in the heavily populated plains of the Ganges and Brahmaputra rivers. Sorting out human-induced hazards from natural causes in such a region is difficult. The Himalayas, where these rivers originate, are a geologically young and active mountain chain that is naturally prone to landslides and massive erosion. Even if the hills remained entirely cloaked in virgin forest, the intense monsoon rains undoubtedly would cause severe flooding in the plains below.[62]

Yet some observers believe flooding has worsened with forest destruction throughout the subcontinent. Researchers at the Centre for Science and Environment in New Delhi estimate that the flood-prone area in India now totals 59 million hectares, more than double a government estimate for the late sixties of 25 million hectares. Between 1913 and 1978, the peak flood level of the Brahmaputra at one monitoring point rose an average of 30.5 centimeters per decade, or nearly 2 meters over the 65-year period. According to these researchers, "We are no longer dealing with disaster events but disaster processes."[63]

"In West Africa, runoff rates recorded from some cultivated and bare soils exceeded those from forest twentyfold."

Likewise, much of the sedimentation of river beds and reservoirs results from natural erosive activity. But road building, careless tree felling, and forest clearing in upland watersheds can exacerbate the problem. In the Philippines, researchers estimate that 1.4 million hectares of upland watershed have been denuded, primarily through uncontrolled logging and unsustainable shifting cultivation practices. Echo sounding measurements show that between 1967 and 1980, the sedimentation rates of the Ambuklao and Binga reservoirs more than doubled. (See Table 8.) By the late seventies, officials already were estimating that silting would halve the Ambuklao project's useful life.[64]



Similarly, in Central America, where forest cover has dwindled from 60 percent of the region's territory in 1960 to 40 percent in 1980, erosion is rampant in many upland watersheds. Heavy siltation has clogged hydroelectric reservoirs, irrigation canals, and coastal harbors. The U.S. Agency for International Development (AID) estimates that given current sedimentation rates, the value today of energy losses from Costa Rica's Cachi hydroelectric project over its lifetime ranges between $133 million and $274 million.[65]

Table 8: The Philippines: Sedimentation Rates in Two Major Reservoirs, 1967–80

| Reservoir | Annual Sedimentation Rate 1967 | Annual Sedimentation Rate 1980 | Change |
|---|---|---|---|
| | (cubic meters per square kilometer) | | (percent) |
| Ambuklao | 3,647 | 8,071 | +121 |
| Binga | 2,857 | 5,844 | +105 |

Source: Nicomedes D. Briones and Jose P. Castro, "Effective Management of a Tropical Watershed: The Case of the Angat River Watershed in the Philippines," *Water International*, December 1986.

Just how much land worldwide needs additional tree cover to stabilize soil and water resources is unknown. Forest analyst Alan Grainger estimates that 87 million hectares of tropical montane watershed (relatively moist and cool upland areas) have been deforested, one-third of the estimated original area covered by montane forest. In 1985, the international task force of tropical forest experts judged that some 160 million hectares of upland tropical watershed have become severely degraded through clearing, overgrazing, poor crop production practices, and other unsustainable land uses.[66]

Neither estimate includes areas in need of tree planting to guard against wind erosion, an important cause of land degradation in some arid and semiarid areas. In India alone, wind erosion has degraded an estimated 13 million hectares; wind-degraded areas at least as large probably exist in China and Africa. Planting to protect land from the wind often takes the form of shelterbelts, rows of trees that break the wind's erosive power. Only a small portion of such land—perhaps a tenth or a twentieth—would actually need to be planted in trees; the remainder would benefit from the shelter they provide.[67]

Some ecological stabilization undoubtedly could be achieved through means other than tree planting: Soil conservation measures, including construction of terraces and planting of grass, could anchor soils in some areas more cheaply. Nevertheless, at least 100 million hectares of tree planting worldwide appears necessary to restore and maintain the productivity of soil and water resources.

Reforesting so large an area—equivalent to the size of Egypt—presents formidable challenges. The benefits of planting trees for ecological reasons are sometimes difficult to quantify, so rates-of-return on project investments may not appear attractive. Since many of the direct beneficiaries of upland watershed rehabilitation are located downstream, who should pay for and carry out the reforestation? Perhaps most important, the worst watershed problems exist not in remote regions, but in areas with intense population pressures. Thus, even given adequate funding and resources, ecological reforestation schemes are bound to fail if they do not at the same time address the needs of the people with no alternative but to overtax upland areas.[68]

"Planting trees to form shelterbelts around cropland can substantially reduce wind erosion, enhance soil moisture, and boost crop yields."

As indicated earlier, experience has shown that local people need economic incentives and the expectation of short-term gains to support and participate in tree planting efforts. A successful strategy for rehabilitating uplands in Nepal, for example, involved transferring control of forestland from the national government to village organizations called panchayats, and paying local people to plant fodder grasses and trees, thus giving them an immediate incentive to join in. Such plantings not only stabilized soils on denuded slopes, they helped meet villagers' basic needs. Livestock were stall-fed, giving the slopes a chance to revegetate. The overall strategy proved successful by almost any measure: Local income increased, fodder became abundant, and fast-growing trees began providing fuel within a few years.[69]



An innovative project getting under way in Colombia tries to remedy the unequal distribution of benefits and costs inherent in many watershed projects. Revenues from a tax on electricity sales from hydropower facilities will pay for reforestation and soil conservation measures in upland watersheds. Lowland dwellers presumably will benefit from reduced flooding and the protection of their power supply, while farmers in the uplands gain from a more productive and stable ecosystem.[70]

Agroforestry holds much promise for stabilizing soil and water resources for many of the same reasons it has such strong potential for increasing fuelwood supplies. In one system, for example, nitrogen-fixing trees are established along the contours of steep slopes, and food crops that reduce sheet erosion are planted in between them. Soil collects behind the hedgerows of trees, forming natural terraces along the contours. Farmers in the highlands of Indonesia have a long tradition of planting the fast-growing legume leucaena in this way. By reducing soil erosion and increasing rainwater infiltration, such strategies enhance upland productivity while helping farmers meet their needs for wood, food, and fodder in a sustainable manner.[71]

In semiarid regions, planting trees to form shelterbelts around cropland can substantially reduce wind erosion, enhance soil moisture, and boost crop yields anywhere from 3 to 35 percent.

Among the most notable windbreak projects is that in the Majjia Valley in Niger. Once heavily wooded, the hills surrounding the valley had become almost completely denuded by the mid-seventies. Winds approached 60 kilometers per hour during the dry season, and annual soil losses averaged 20 tons per hectare. In 1974, the villagers requested help from the government forestry officer to establish a nursery of neem, a deep-rooted tree native to Asia that produces wood good for both fuel and timber, oil useful as lamp fuel, and a natural insecticide that helps protect crops.[72]

Government foresters and Peace Corps volunteers selected the best locations for the windbreaks, but the farmers themselves did the planting. Although the trees occupied up to 15 percent of the cropland area, crop yields were a fifth above those of equal areas of unprotected land, more than compensating for the area taken out of cultivation. By 1987, planted trees were protecting more than 71,000 hectares. In *The Greening of Africa*, Paul Harrison sums up the keys to this project's success: "The technology was appropriate and simple, the species well adapted to local conditions. The package delivered the protection that had been promised. The costs for the majority of farmers were slight. The benefit in increased crop production was rapid, and perceived by the farmers."[73]

Rehabilitating tens of millions of hectares of degraded land will require duplicating numerous times the successes of projects like those in Nepal and Niger. Such efforts—designed to benefit local people in the short term while stabilizing the resource base for the long term—illustrate that reforestation involves more than establishing plantations, and that trees do more than provide wood.

## Forests and Climate Change

Forests play a crucial role in the global cycling of carbon. The earth's vegetation and soils hold some 2 trillion tons of carbon, roughly triple the amount stored in the atmosphere. When trees are cleared or harvested, the carbon they contain, as well as some of the carbon in the underlying soil, is oxidized and released to the air, adding to the

"The earth's vegetation and soils hold some 2 trillion tons of carbon, roughly triple the amount stored in the atmosphere."

atmospheric store of carbon dioxide ($CO_2$). This release occurs rapidly if the trees are burned, but slowly if they decay naturally.[74]



Since 1860, forest clearing has contributed some 90–180 billion tons of carbon to the atmosphere, compared with 150–190 billion tons from the burning of coal, oil, and natural gas. Together, deforestation and the combustion of fossil fuels have raised the level of $CO_2$ in the atmosphere from 280 parts per million in the immediate preindustrial period to 348 parts per million in 1987, a 24-percent increase. Like a one-way filter, carbon dioxide lets energy from the sun pass through it but absorbs the longer wavelength radiation emitted from the earth—a phenomenon dubbed "the greenhouse effect." The result is an anticipated warming of the earth, which some recent findings suggest may already be under way. A continued rise in $CO_2$ levels, along with increases in the concentrations of other greenhouse gases, threatens the world with potentially catastrophic shifts in climate.[75]

The annual release of carbon from the loss of forests probably exceeded that from fossil fuels until about mid-century, when the pace of industrialization and the use of oil rose markedly. By then, most clearing for agriculture in North America and Europe had ceased, and the forested area in those regions became fairly stable. Today the bulk of $CO_2$ added to the atmosphere by land use changes comes from the tropics.[76]

Estimates of the amount of carbon released through forest clearing have varied greatly in recent years. One recent study places the net contribution from tropical lands in 1980 between 0.4 billion and 1.6 billion tons; another sets it between 0.9 billion and 2.5 billion tons, or between 20 and 50 percent as much as fossil fuel combustion contributed that year. Obviously, more research is needed to refine these estimates. The large ranges reflect uncertainties about the rates of forest conversion, the extent of regrowth after clearing, the amount of biomass (and carbon) contained in the lands being cleared, and how quickly the carbon makes its way into the atmosphere.[77]

Using their best judgments on these factors, Richard Houghton of the Woods Hole Research Center in Massachusetts and several colleagues have painted a useful picture of the geographic distribution of carbon emissions from land use changes. (See Table 9.) Based on their mid-points of estimated ranges, 40 percent of the total net release of carbon from land conversion comes from tropical America, 37 percent from tropical Asia, and 23 percent from tropical Africa. Just five countries account for half of all net carbon releases from deforestation; the loss of forests in Brazil alone contributes one-fifth of the total. (See Table 10.)

Although the cutting and burning of forests clearly adds significantly to the $CO_2$ buildup, the way remaining forests worldwide respond both to the buildup itself and to the resulting planetary warming could exert an even greater influence on the earth's future climate.

**Table 9: Estimated Net Release of Carbon to the Atmosphere from Tropical Deforestation, by Region, 1980**

| Region | Forest Cover | Estimated Net Carbon Release | Share of Total Carbon Release |
|---|---|---|---|
| | (million hectares) | (million tons) | (percent) |
| Tropical America | 1,212 | 665 | 40 |
| Tropical Asia[1] | 445 | 621 | 37 |
| Tropical Africa | 1,312 | 373 | 23 |
| Total | 2,969 | 1,659 | 100 |

[1]Releases from tropical Asia are nearly as high as from tropical America (despite a much smaller forest area) not because of a higher deforestation rate but because a hectare of moist tropical forest in Asia contains more carbon than a hectare of tropical forest in Latin America.

Sources: 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*, February/April 1987; U.N. Food and Agriculture Organization, *Tropical Forest Resources*, Forestry Paper 30 (Rome: 1982).

**Table 10: Estimated Net Release of Carbon to the Atmosphere from Tropical Deforestation, by Country, 1980**



| Country | Net Carbon Release[1] | Share of Total |
|---|---|---|
| | (million tons) | (percent) |
| Brazil | 336 | 20 |
| Indonesia | 192 | 12 |
| Colombia | 123 | 7 |
| Côte d'Ivoire | 101 | 6 |
| Thailand | 95 | 6 |
| Laos | 85 | 5 |
| Nigeria | 60 | 4 |
| Philippines | 57 | 3 |
| Burma | 51 | 3 |
| Peru | 45 | 3 |
| Ecuador | 40 | 3 |
| Vietnam | 36 | 2 |
| Zaire | 35 | 2 |
| Mexico | 33 | 2 |
| India | 33 | 2 |
| Others | 337 | 20 |
| Total | 1,659 | 100 |

[1]Figures are midpoints of estimated ranges; the estimated total release from tropical deforestation in Houghton et al. ranges from 900 million to 2.5 billion tons.

Source: 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*, February/April 1987.

Higher $CO_2$ levels might enhance the growth of trees, causing them to remove more carbon from the atmosphere, which in turn would dampen the warming. Greenhouse operators take advantage of this fertilizing effect to boost crop production; they set the $CO_2$ concentration in greenhouse air two to three times higher than in the natural atmosphere. So far, however, no convincing evidence suggests that natural forests would respond in this way.[78]

A second way forests might respond has more ominous implications. Ecologist George Woodwell suggests that rising temperatures from the buildup of $CO_2$ and other greenhouse gases could substantially increase the respiration rates of trees and soil microorganisms, especially in the middle to higher latitudes where the temperature rise will be most pronounced. When respiration outpaces photosynthesis, trees release more carbon dioxide to the atmosphere than they remove, as those in seasonal forests do during autumn and winter when they lose their leaves. A temperature-induced increase in respiration could cause a significant additional release of $CO_2$, reinforcing the very buildup that initiated the warming.[79]

If respiration exceeded photosynthesis for an extended period, trees would stop growing, and ultimately die. New species better adapted to the altered climate eventually would replace the old ones, but for several decades trees might die off with little replacement. A large-scale forest dieoff could release enormous amounts of carbon to the atmosphere—perhaps hundreds of billions of tons, Woodwell maintains, depending on the speed of the warming. He notes, "the sudden destruction of forests by air pollution, now being experienced in northern and central Europe and in the eastern mountains of North America, is but a sample of the destruction that appears to be in store."[80]

Woodwell's scenario might never become reality. Indeed, ecologists do not yet agree on how forests will respond to climate change, or even on whether that response will add $CO_2$ to the atmosphere or remove it. Another possibility, for example, is that higher temperatures would increase rates of organic decomposition, which in turn would release nutrients to the soil and thus potentially boost the productivity of trees. Since trees would be growing faster, they would remove more $CO_2$ from the atmosphere, thus mitigating the warming. The uncertainty about forests' response to the warming looms large, since the potential for a strong feedback—positive or negative—clearly exists.[81]



Since the ongoing loss of forest cover contributes significantly to the $CO_2$ buildup, concerted efforts to protect existing forests and to plant more trees could help slow it. It is unfair to expect developing countries to invest substantial resources in tree planting solely to ward off global warming. More immediate needs—including handling massive amounts of debt—command a higher priority. Yet satisfying rising demands for fuel and industrial wood and stabilizing soil and water resources are among the pressing needs many countries face; planting trees for these purposes would have the added benefit of sequestering more carbon from the atmosphere during the period that the trees are growing.

Previous sections of this report provide ballpark estimates of reforestation needed for fuelwood, industrial wood, and ecological rehabilitation of 55 million hectares, 10 million hectares, and 100 million hectares, respectively. A larger area would actually be involved, since many of the trees presumably would be planted on and around farms as part of agroforestry systems rather than in concentrated plantations. Obviously, some planting to meet fuel and industrial wood needs would also serve to stabilize soil and water resources, but at this stage the extent of overlap is impossible to judge. For the sake of a rough estimate, assuming 35 million hectares of overlap seems reasonable, leaving the equivalent of 130 million hectares of needed planting.

One additional adjustment is necessary. Some of the trees planted for fuelwood would offer little carbon-fixing benefit, since the carbon they accumulate during growth would quickly be released to the atmosphere when they were burned. However, a large share of the estimated 55 million hectares of planting for fuelwood aims to make fuelwood use sustainable by ensuring that new growth exceeds cutting. Extrapolating from FAO estimates of unmet demand for wood in 1980, it is reasonable to assume that 20 percent (about 10 million hectares) of fuelwood planting would be burned in the short term, while 80 percent (about 45 million hectares) would expand the resource base and thereby accumulate carbon for as long as the trees continue to grow. Virtually all the area planted for industrial wood and ecological stabilization would yield carbon-fixing benefits. Thus the total area providing this service would be approximately 120 million hectares.[82]

How much would terrestrial carbon emissions be reduced as a result of these 120 million hectares? Too many uncertainties exist to answer this question accurately, but some back-of-the-envelope calculations can shed light on reforestation's potential role in mitigating the $CO_2$ buildup.

A fairly fast-growing tropical hardwood species yields on the order of 10–14 tons of biomass per hectare per year, depending on age and harvest schedule. Half that weight—about 6 tons per hectare—is carbon that has been assimilated from the atmosphere through photosynthesis. Reforestation would also increase the amount of carbon stored in soils. In shifting cultivation systems in tropical Asia, for example, soil carbon increases an average of about 1 ton per hectare per year during the fallow phase, the period of tree regrowth. Soils beneath planted trees would store a similar amount, but possibly somewhat less if litter were removed for fuel or fodder. Assuming conservatively that soil carbon storage would increase about a half-ton per hectare annually on reforested land, the total carbon-fixing benefit of tree planting would be 6.5 tons per hectare per year.[83]

At that rate, the equivalent of 120 million hectares of trees would sequester roughly an additional 780 million tons of carbon annually until the trees reach maturity, reducing net carbon releases from tropical terrestrial systems by 47 percent (assuming a current net release of 1.66 billion tons). Of course, concerted efforts to slow deforestation would also be a crucial component of any strategy to limit carbon emissions from tropical lands. Halving the $CO_2$ contribution from deforestation in Brazil, Indonesia, Colombia, and Côte d'Ivoire, for example, would cut total net carbon releases from tropical forests by more than a fifth. Together, that achievement and the

"Abandonment of a significant share of cropland and the replanting and regrowth of trees has put Europe on the positive side of the terrestrial $CO_2$ ledger."

carbon storage benefits from 120 million hectares of trees could reduce net carbon emissions from terrestrial systems by two-thirds.



Houghton and his colleagues estimate that at present the only regions in which terrestrial ecosystems are accumulating more carbon each year than they are releasing are Europe and, possibly, Japan and South Korea. Abandonment of a significant share of cropland and the replanting and regrowth of trees has put Europe on the positive side of the terrestrial $CO_2$ ledger. Europe's estimated accumulation of carbon in 1980 nearly offset carbon releases from deforestation in India. Continued forest damage from air pollution and acid rain, however, could turn the region's terrestrial systems back into a net $CO_2$ contributor.[84]

In the United States, actions taken as a result of the Food Security Act of 1985 should augment the nation's terrestrial store of carbon. The act created a Conservation Reserve under which some 16 million hectares of highly erodible cropland are to be taken out of production from 1986 through 1990 and planted in trees or grass. A hectare of temperate woodland or grassland stores on the order of 40–45 more tons of carbon than a hectare of cultivated cropland. Assuming a yearly net carbon accumulation rate of 2 tons per hectare as the land undergoes conversion, the 16 million hectares placed in the reserve would assimilate a total of 32 million tons of carbon annually for the next couple of decades. U.S. and Canadian lands were estimated to contribute 25 million tons of carbon to the atmosphere in 1980; thus, depending on overall trends in forest cover and wood use, the Conservation Reserve might make North American terrestrial systems a net sink for carbon.[85]

Measures that curb the use of fossil fuels—today's biggest contributor to the buildup of carbon dioxide in the atmosphere—offer the greatest opportunities to slow the rate of global warming. Boosting energy efficiency and shifting to alternative energy sources will buy the greatest degree of climate insurance for the dollar. Yet the rough calculations presented here suggest that efforts to preserve existing tropical forests and to plant trees—important for a host of other reasons—have a significant role to play in slowing the $CO_2$ buildup.

 Nature employs a wide variety of methods for expanding tree cover: coconuts that float between tropical islands, aerodynamic seeds, and luscious fruits that attract animal carriers. Strategies equally diverse and ingenious are needed to mobilize human energy and financial resources for tree planting sufficient to satisfy fuel and industrial wood needs, to stabilize soil and water resources, and to slow the carbon dioxide buildup. As with nature's seed-dispersal strategies, the key to success is designing planting programs that fit the particular niche—the economic, social, and cultural setting—in which people live and work.

As indicated earlier, tree planting programs are most effective when local people are involved in their planning and implementation and perceive their own interest in success. If fodder is a critical need, for example, a project that promotes a nonbrowsable species like eucalyptus will receive little popular support. Knowledge of villagers' access to cash, seasonal patterns of labor, and preferences for tree species is also crucial. Designing a reforestation project without local input is like letting a doctor prescribe treatment without asking the patient what hurts.

Not surprisingly, given their emphasis on grassroots participation, international nongovernmental organizations (NGOs) have orchestrated some of the most successful reforestation projects to date. Funneling more aid through them rather than official channels could improve reforestation's prospects. Groups such as CARE in the United States and Oxfam in the United Kingdom have flexibility and local-level experience that government forest departments often lack, making them useful agents for encouraging rural tree planting.

In one farsighted program, for instance, the U.S. Agency for International Development contracted with CARE and the Pan American Development Foundation to encourage agroforestry and tree farming in Haiti. The project's success—which includes planting more than 35 million seedlings between 1982 and 1987—stems in part from the

"Designing a reforestation project without local input is like letting a doctor prescribe treatment without asking the patient what hurts."

value and efficiency of working through NGOs that had grassroots networks already in place.[86]



Much could also be gained by reinforcing the efforts of small, local NGOs. Around the world, women's associations, peasant collectives, and church groups have taken up tree planting; in Kerala, India, alone some 7,300 organizations are involved. Because local groups reflect the needs, abilities, and limitations of their communities, their projects are more likely to succeed, given adequate resources and technical assistance. In Kenya, for example, the Greenbelt Movement—sponsored by the National Council of Women of Kenya—has involved more than 15,000 farmers and a half-million schoolchildren in establishing 670 community nurseries and planting more than 2 million trees.[87]

One way to inspire greater NGO involvement in forestry is for existing aid agencies and development organizations to offer matching grants for funds raised by local organizations. Such a program sponsored by AID, for example, inspired CARE to greatly increase its involvement in agroforestry between 1981 and 1984. CARE augmented funding for agroforestry roughly sevenfold and added 17 new agroforestry projects to its agenda. Some 90,000 people benefited from the planting of about 8.6 million trees.[88]

Also promising is the creation of "windows" within existing funding organizations willing to accept project proposals directly from the NGO community. Many international relief organizations, such as Lutheran World Relief and Catholic Relief Services, already have such offices, as do a few bilateral assistance agencies. Understandably, some international donors are reluctant to take on the administrative headaches of dealing with numerous small organizations that can each absorb only limited funds. But the outstanding performance of groups like the Greenbelt Movement highlights the importance of supporting such efforts. One option is for donors to channel funds through an umbrella organization that in turn distributes money to local projects; KENGO (Kenyan Energy NGOs), a consortium of 200 smaller groups, plays just such a role.[89]

Even when aid goes through government channels, reforestation efforts could benefit from more innovative extension strategies. Most early projects were unsuccessful in transforming foresters into rural extension agents. For decades foresters saw their mission as defending forests from rural villagers, not encouraging people's involvement in tree planting and management. Experience in Asia suggests that village "motivators" or existing agricultural extension agents may be better positioned than foresters to advance rural tree planting, especially in the context of agroforestry. World Bank projects in Kenya, India, and Malawi use foresters to train agricultural workers about multipurpose tree species rather than work with villagers directly. In Thailand, AID has pioneered the use of nongovernmental "interface teams," groups of three people—including one woman and one ethnic minority—who go to live in a village as community organizers. The emphasis in this approach on reaching women is an essential yet often ignored aspect of forestry outreach.[90]

Even the best project designs, however, will not improve prospects for accelerated planting unless reforestation becomes a development priority. For decades, forestry has been the poor stepchild of development agendas emphasizing agricultural projects and capital-intensive energy schemes. Developing countries traditionally have undervalued forestry because national accounting methods often ignore the ecological and social benefits of forests. A World Bank survey of more than 60 countries found that forestry budgets accounted for less than 2 percent of the combined government outlays for energy and agriculture. International donors likewise have shied away from forestry investments, preferring projects with quick, certain, easily quantifiable benefits. From 1980 through 1984, the major development banks allocated less than 1 percent of their annual financing to forestry, and the U.N. Development Programme (UNDP), only 2 percent.[91]

The late 1985 launch of the Tropical Forestry Action Plan, however, holds promise of elevating forestry to its rightful place among development priorities. Jointly sponsored by FAO, UNDP, the World Resources Institute, and the World Bank, the plan calls for accelerated investments of $8 billion over five years in tree planting projects and efforts to arrest deforestation. Development assistance organizations

"Reaching women is an essential yet often ignored aspect of forestry outreach."

are to contribute half the needed funding ($800 million a year), with the remainder coming from national governments and the private sector.[92]



Already the Action Plan has stepped up global funding for forestry and spawned increased cooperation among development agencies. The World Bank, the Asian Development Bank, and several bilateral aid agencies plan to more than double their annual assistance to forestry. Collectively, global aid contributions to forestry are likely to increase from roughly $600 million in 1984 to over $1 billion in 1988. Donors are also working together with national governments on a series of forest sector reviews, aimed at quantifying the ecological and social benefits of forests in individual countries and suggesting actions that would put forest management on a sustainable footing. Reviews have been completed for 6 countries and are currently under way for 21 more.[93]

Ultimately, however, the response of developing-country governments will determine the impact of the Action Plan. International initiatives are only as strong as the national initiatives they inspire. Both South Korea and China have demonstrated that strong political commitment together with charismatic leadership and adequate resources are prerequisites for successful national campaigns to increase tree cover. Yet recent trends in China suggest that even then, achieving an expansion of tree cover in the face of increasing demand for forest products presents a formidable challenge.[94]

The Chinese government claims that between 1948 and 1978, trees were successfully established on roughly 28 million hectares, and forest cover increased from 8.6 to 12.7 percent of the nation's land. During the eighties, however, this effort appears to have lost ground. Between 1979 and 1983, forest cover declined by 5 million hectares. Annual plantings of more than 4 million hectares apparently could not keep pace with the growing demand for timber sparked by the economic reforms of 1979. For the first time, rural people were allowed to build their own homes, and over half the rural households did. From 1981 through 1985, housing construction alone consumed a total of 195 million cubic meters of timber, about a year's growth from all of China's forests.[94]



In 1985, annual planting in China doubled to 8 million hectares, giving renewed cause for optimism. Tree survival rates that had averaged only 30 percent also are improving, in large part because the government now allows peasants to own the trees they plant. By summer 1986, more than 33.3 million hectares of barren hills had been allocated for tree planting to 50 million rural households, and 40 million hectares were separately contracted to farmers. Peasants have been granted sole right to use the land for 30–50 years, a right that can be inherited. Although the government seems unlikely to achieve its ambitious target of 20-percent forest cover by the year 2000, the combination of increased planting and better management, if sustained, could allow the nation's tree cover to begin increasing again.[95]

India's Rajiv Gandhi recently joined the ranks of political leaders who have elevated reforestation to the level of a national crusade. Recognizing that deforestation had brought his nation "face to face with a major ecological and socio-economic crisis," Prime Minister Gandhi assigned forestry a central place in his development agenda for 1985–90. He roughly tripled funding for forestry, reorganized his Ministries to give forestry new prominence, and created a National Wastelands Development Board to spearhead a "peoples' movement for afforestation." Significantly, Gandhi recognizes that local people are India's greatest resource for reforestation. He has authorized the Development Board to distribute funds directly to schools, women's groups, and other NGOs for tree planting and community nurseries. Although this campaign undoubtedly has faltered as villagers and the government respond to India's worst drought of the century, it is hoped that planting will resume in full force once the crisis subsides.[96]

In addition to providing active leadership, governments can promote reforestation by molding their laws and policies to encourage tree planting. Because peasants are reluctant to plant trees without assurance of benefits, policies related to land and tree tenure are particularly important. Ironically, some laws originally designed to protect trees actually limit their propagation. In Honduras and the Dominican

"Forestry research
in the Third World
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Republic, where all trees are owned by the government, penalties imposed for cutting trees without permission discourage tree planting. By contrast, laws—such as exist in India and China—that grant ownership of trees to the people who plant them (regardless of who owns the land) tend to encourage reforestation.[97]



The International Tropical Timber Agreement (ITTA), ratified in 1985, also holds promise of promoting reforestation for industrial purposes. Unique among commodity agreements, the ITTA called for national policies that "encourage sustainable utilization and conservation of tropical forests and their genetic resources." The Agreement established a Tropical Timber Council currently consisting of 41 producer and consumer nations to oversee three standing committees—on market intelligence, reforestation and forest management, and forest industry. So far, the Council has approved 12 projects—totaling more than $2.8 million—on reforestation, sustainable management, and market trends. If it so chooses, the Council could also be instrumental in negotiating lower import taxes on processed wood products in industrial countries. This would help infant processing industries to develop in producer countries without heavy subsidy.[98]

With considerable tree planting needed on marginal land and as part of agroforestry systems, increased attention to basic research is crucial. Progress lies not simply in planting more trees, but in improving the productivity, usefulness, and survival of those that are planted. A focused effort on breeding multipurpose trees that endure droughts and grow well in marginal environments could greatly improve prospects for successful reforestation. Unfortunately, forestry research in the Third World is currently underdeveloped, underfunded, and highly skewed toward improving processed forest products. Relatively little effort goes to forest protection, ecosystem stability, or tree breeding for agroforestry.[99]

Indeed, what is needed in the coming decade is an effort somewhat akin to the agricultural Green Revolution of the sixties: a dedication to developing genetically improved tree species and to extending widely the technical and financial resources for reforestation. Forestry's Green Revolution, however, needs to promote indigenous tree species and diversified agroforestry systems, and must strive to benefit marginalized populations, including the landless. Accelerated planting that does not benefit the poor only masquerades as success.

Tree planting may lack the glory and grandeur of a medical breakthrough, a huge hydropower dam, or any number of technological marvels. But its unmatched potential for stabilizing simultaneously the carbon cycle, land and water resources, rural energy supplies, and people's livelihoods makes it a top priority for economic and social development. Covering the equivalent of 130 million hectares with forest by the year 2000 would entail successfully establishing some 18.4 billion trees annually. The target sounds staggering, but it would only require each person now living in the Third World to plant and care for five seedlings a year. Reforesting the earth is possible, given a human touch.

1. Preagricultural number from E. Matthews, "Global Vegetation and Land Use," *Journal of Climate and Applied Meteorology*, Vol. 22, 1983, pp. 474–487; for 1980 number, see Table 1.

2. John F. Richardson, "World Environmental History and Economic Development," in William C. Clark and R. E. Munn, eds., *Sustainable Development of the Biosphere* (New York: Cambridge University Press, 1986); International Institute for Environmental Studies, *European Environmental Yearbook 1987* (London: DocTer International UK Ltd., 1987); Robert G. Albion, *Forests and Sea Power: The Timber Problem of the Royal Navy 1652–1862* (Cambridge, Mass.: Harvard University Press, 1926); U.S. Forest Service, U.S. Department of Agriculture (USDA), *Timber Resources for America's Future*, Forest Resources Report No. 14 (Washington, D.C.: U.S. Government Printing Office, 1958).

3. Total world land area equals 13,081 million hectares, excluding Antarctica, Greenland's tundra, and inland water bodies. Area in crops equals 1,477 million hectares, according to U.N. Food and Agriculture Organization (FAO), *1985 Production Yearbook* (Rome: 1986).

4. FAO, *Tropical Forest Resources*, Forestry Paper 30 (Rome: 1982).

5. Philip Fearnside, "Spatial Concentration of Deforestation in the Brazilian Amazon," *Ambio*, Vol. 15, No. 2, 1986; Philip Fearnside, "Deforestation in the Brazilian Amazon: How Fast Is It Occurring?" *Interciencia*, Vol. 7, No. 2, 1982; Centre for Science and Environment, *The State of India's Environment 1984–85* (New Delhi: 1985); FAO, *Tropical Forest Resources*; K.D. Singh, FAO, Rome, private communication, July 15, 1987.

6. Annual planting rate for Brazil was projected by FAO for 1981–85 in FAO/U.N. Environment Programme (UNEP), *Los Recursos Forestales de la America Tropical: Proyecto de Evaluación de los Recursos Forestales Tropicales*, Informe Tecnico No. 1 (Rome: 1981); *Information Please Almanac 1988* (New York: Houghton Mifflin Company, 1988).

7. Kenya example from Peter A. Dewees, Forest Economist, Nairobi, Kenya, private communication, July 7, 1987; Rwanda example from R. Winterbottom, "Rwanda Integrated Forestry and Livestock Project," Report of the Rural Forestry Preparation Mission (Phase II), FAO/World Bank, Washington, D.C., 1985.

8. FAO, *Tropical Forest Resources*; Alan Grainger, "Estimating Areas of Degraded Tropical Lands Requiring Replenishment of Forest Cover," *International Tree Crops Journal*, Vol. 5, No. 1–2, 1988.

9. B. Bowonder et al., "Deforestation Around Urban Centres in India," *Environmental Conservation*, Vol. 14, No. 1, Spring 1987.

10. Norman Myers, "The Hamburger Connection: How Central America's Forests Become North America's Hamburgers," *Ambio*, Vol. 10, No. 1, 1981; H. Jeffrey Leonard, *Natural Resources and Economic Development in Central America* (Washington, D.C.: International Institute for Environment and Development, 1987); Philip M. Fearnside, "Land-Use Trends in the Brazilian Amazon Region as Factors in Accelerating Deforestation," *Environmental Conservation*, Summer 1983.

11. "Tropical Forestry Plan May Save Asia's Forests," *World Wood*, October 1987; Côte d'Ivoire example from "Africa Must Alter Policies to Avert Ecological Disaster," *World Wood*, October 1986.

12. In Latin America, 5–10 cubic meters per hectare are harvested out of a total standing volume of 300–400 cubic meters, in West Africa 10–15 cubic meters are harvested, and in Southeast Asia in richer dipterocarp forests, up to 60 cubic meters, according to John Spears, "Saving the Tropical Forest Ecosystem," unpublished paper, World Bank, Washington, D.C., June 1983; for a listing of studies documenting secondary damage from selective logging, see Norman Myers, *The Primary Source: Tropical Forests and Our Future* (New York: W.W. Norton & Co., 1984); figure for logged-over forest from FAO, *Tropical Forest Resources*; Robert O. Blake, "Moist Forests of the Tropics—A Plea For Protection and Development," *Journal '84*, World Resources Institute, Washington, D.C., 1984.

13. George Ledec, "The Political Economy of Tropical Deforestation," paper presented at the Second World Congress on Land Policy, Cambridge, Mass., June 20–24, 1983.

14. Ibid.; Marcus Colchester, "Programme Slashed in Response to Transmigration Campaign," *The Ecologist*, Vol. 17, No. 1, January/February 1987.

15. "The Pioneers Are Homesick," *The Economist*, December 19, 1987; Michael Vatikiotis, "Resettlement Rethink," *Far Eastern Economic Review*, October 29, 1987.

16. "U.S. Asks World Bank To Make Safeguarding Environment a Priority," *Wall Street Journal*, July 3, 1987; Section 537(a), Environmental Concerns, Continuing Resolution, Public Law 100–202 (see the Omnibus Appropriations Act, December 22, 1987).

17. F.C. Hummel, "In the Forests of the EEC," *Unasylva*, No. 138, 1982; International Institute for Environmental Studies, *European Environmental Yearbook 1987*.

18. International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, "Forest Damage and Air Pollution: Report on the 1986 Forest Damage Survey in Europe," Global Environment Monitoring System, UNEP, Nairobi, mimeographed, 1987.



19. U.S. forest area declined from 385 million hectares in 1630 to 249 million hectares in 1920, according to U.S. Forest Service, *Timber Resources for America's Future*. Forest area in 1982 adapted from U.S. Forest Service, *America's Renewable Resources: A Supplement to the 1979 Assessment of Forest and Rangeland in the U.S.* (Washington, D.C.: USDA, 1984); note that figure cited in text omits forest area for Alaska and Hawaii. Total U.S. forest area of United States in 1963 was approximately 307 million hectares according to U.S. Forest Service, USDA, *Timber Trends in the U.S.*, Forest Resource Report No. 17 (Washington D.C.: U.S. Government Printing Office, 1965); forest area of contiguous states in 1963 was estimated by subtracting the 48 million hectares of forest listed for Alaska and an additional 804,000 hectares to approximate the forest area of Hawaii. For a description of U.S. forest cover trends, see "The Evolving Use and Management of Our Forests, Grassland and Croplands," in Council on Environmental Quality, *Environmental Quality 1985* (Washington D.C.: U.S. Government Printing Office, 1987).

20. Gordon T. Goodman, "Biomass Energy in Developing Countries: Problems and Challenges," *Ambio*, Vol. 16, No. 2–3, 1987.

21. FAO, *Fuelwood Supplies in the Developing Countries*, Forestry Paper 42 (Rome: 1983).

22. Bina Agarwal, *Cold Hearths and Barren Slopes: The Woodfuel Crisis in the Third World* (Riverdale, Md.: The Riverdale Co., Inc. 1986); Nepal figure from Robert Winterbottom and Peter T. Hazelwood, "Agroforestry and Sustainable Development: Making the Connection," *Ambio*, Vol. 16, No. 2–3, 1987.

23. International Task Force (ITF), *Tropical Forests: A Call to Action, Part I: The Plan* (Washington, D.C.: World Resources Institute, 1985).

24. The energy efficiency of traditional charcoal-making processes tends to be about 30 percent. Although some efficiency will be recouped because charcoal stoves are slightly more efficient (at 25 percent) than wood-burning stoves (at 18 percent), the overall efficiency will probably still be close to 50 percent. See Gerald Foley, *Charcoal Making in Developing Countries* (Washington, D.C.: International Institute for Environment and Development, 1986), and Goodman, "Biomass Energy." West African urban figure from Willem Floor, "A Strategy for Household Energy in West Africa" (draft), World Bank, Washington, D.C., June 1987.

25. Paul Harrison, *The Greening of Africa* (New York: Viking/Penguin, Inc., 1987).



26. World Bank, *Sudan Forestry Sector Review*, Report No. 5911-SU (Washington, D.C.: 1986); ITF, *Tropical Forests, Part I.*

27. John Spears, Senior Forestry Advisor, World Bank, Washington, D.C., private communication, September 24, 1987.

28. For a review of agroforestry's potential, see Winterbottom and Hazelwood, "Agroforestry and Sustainable Development."

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