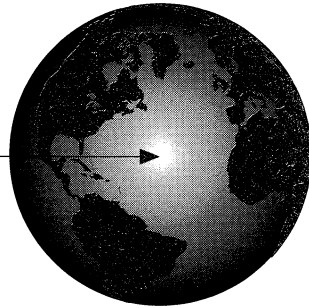


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THE WORLD'S FORESTS:

CONFLICTING SIGNALS

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February 1995

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Institute



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EXECUTIVE SUMMARY

A number of diverse currents and pressures are simultaneously being brought to bear on the world's forests. In the tropics, forestlands are continuing to be converted to other land uses at increasing rates. By contrast, the temperate forestlands have stabilized and are expanding in most industrial countries. The countervailing trends witnessed in the forests of the world cause alarm to those who perceive them to be in rapid and perhaps irreversible decline. But to others, the forests' ability to expand and flourish, providing society with both commodity and environmental outputs, demonstrates an amazingly adaptable and resilient ecosystem which is expected to continue providing a host of goods and services into the future. If the forests are to be preserved for future generations, it is imperative to base any assessment of the condition of global forests on accurate data and a clear understanding of the dynamic between the forest and the institutional structures of the community that uses it.

It has become commonplace, even fashionable to blame deforestation on industry's rise. Yet private forest lands have accounted for eighty five percent of total tree planting and seeding in the U.S. in recent years. The forests of the Northern Hemispheric industrial countries have been steadily expanding for decades while continuing to provide nearly 75 percent of the world's industrial wood production. The United States has been the world's top producer of timber since World War II. Yet the volume of our national forests today is greater than it was 50 years ago, while forest area in the U.S. has remained fairly constant over the past 75 years. Indeed, improved tree growing technology, the escalation of deliberate efforts to promote forest growth through tree planting, and improved control over wildfire have been influential agents of forest preservation. Testimony to the success of such efforts is the 30 percent increase of forest biomass in the northern Rocky Mountains since the middle of the Eighteenth Century.

Conversely, the rate of forest conversion in the tropical areas increased from 0.6 percent to 0.8 percent in 1993. The 1,910 million hectares of land covered by tropical forests in 1980 was reduced to 1,756 million hectares by 1990. This occurred despite an impressive 2.6 million hectare a year expansion of tropical plantation forests throughout the 1980s which totaled 30.7 million hectares of tropical plantation forest land in 1992.

Why is it that industrialized countries do a better job than developing countries in preserving their forests? Comparing the alarming rates of land conversion in the tropical forests of developing countries to the stable rates of the temperate forests in the industrialized regions evinces a clear relationship

between levels of economic development and degrees of forest modification. Part of the reason for this is that agricultural expansion, not commercial logging, is a major cause of deforestation. Developed countries in the temperate regions have achieved relative land use stability while the developing countries in the tropics are still in a mode of agricultural expansion. Additionally, industrialized countries have well-developed institutions of land tenure, property rights, enforcement capabilities, and judicial systems that encourage long-term commitments to the land. The absence of such systems in the developing tropical regions encourages the slash-and-burn agriculture that exacerbates deforestation.

Historically, humans everywhere have interacted with and “disturbed” the forest. As humans progressed and became agriculturists, rather than simple hunter-gatherers, they found it necessary to modify natural ecosystems. However, the land conversion process is not one-way, flowing only from forests to cleared lands. Lands once cleared may be converted back into forests either as plantations or as naturally regenerated forests.

Forests are not and have never been unchangeable. Being biological systems they have an amazing resiliency and ability to adapt to fluid conditions, whether these changes are the result of nature or humans. Thus, although the forests of the temperate world have experienced many anthropogenic disturbances over the millennia, in many respects they are in remarkably good condition. In vast areas of the globe much of the natural forest is intact and minimally effected by human disturbances. In addition, plantation forests are growing in importance and increasingly deflecting timber harvesting pressures away from natural forests. It is likely that the world’s forests will be stabilized early in the next century.

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INTRODUCTION

For tens of thousands of years humans met most of their basic needs by foraging the land. Game, forest foods, clean water, fuelwood as well as poles and construction materials were available for only the cost of extraction. Gradually, hunting evolved into herding and humans eventually invented agriculture.

The expansion of human populations led to the need for more agricultural lands. In Europe, India, China, as well as pre-Colombian America and elsewhere, lands were gradually modified and converted to accommodate cropping and pasture. Although timber and other products were drawn from the forest, the major force behind the reduction of forests was the expansion of agriculture.

It was not until the 17th century that the large-scale expansion of cropland and pasture became a worldwide phenomena. Even since then, deforestation pressures have been uneven. One or two centuries ago land clearing pressures were greatest in the temperate areas, principally North America and Europe. The tropics, while experiencing deforestation in some places, were far less impacted. Today, the situation is reversed. In

In Europe, the major force behind the reduction of forests was the expansion of agriculture.

many areas of the tropics governments, as well as individuals, still see the forest as an impediment to economic development. Forest clearing is viewed as a social good, providing the society with increased crop land. Just as forestlands were cleared along the eastern seaboard two centuries ago in America to provide agricultural lands, lands today are being cleared in the frontier areas of tropical South America and Asia.

However, commercial logging apparently is not a major cause of deforestation since temperate forests, which produce most of the world's timber, are essentially stable. The past few decades have seen the rapid expansion of tree planting and the establishment of forest plantations. Although agriculture replaced foraging for food in much of the world millennia ago, the transition from wood foraging to growing wood is only now taking place. Just as humanity moved from hunting and gathering wild resources to herding and farming, forestry today is in transition from simply drawing on nature's bounty to planting, managing and harvesting trees utilizing the agricultural model for wood production.

Today, much of the world's industrial wood comes from plantation forests established throughout the globe from Spain to New Zealand, and Chile to South Africa. Almost all of the timber harvested in the U.S. comes from second growth or plantation forests. The "undisturbed" native forests of the U.S. are almost wholly unavailable for timber harvests by virtue of their being part of the park, preservation and wilderness system or in other public management. The Forest Service has almost entirely ceased timber harvesting in recent years.

Similarly, most of the timber harvests in Europe come from planted or second growth forests. Many of these lands had earlier been cleared and farmed before being returned to forest as plantations.

The use of a cropping mode to produce wood has had and will continue to have profound effects on the remaining natural forests. Just as agriculture reduced food foraging pressures on natural habitats by increasing crop productivity, so too plantation forests with their high level of productivity are reducing the pressures on the remaining natural forests. And this trend is likely to strengthen since the economics of plantation production are favorable in many locations (Sedjo 1983). The world's current industrial wood consumption requirements could be produced on an area of about 200 million hectares of good forestland, an area only about 5 percent of the world's total current forestland. Finally, large areas of the world's forests are protected either by the establishment of reserves or through their own inaccessibility.

How are these forests to be viewed in any broad global assessment?

THE BEGINNINGS

Forests have been affected by human activities for tens of thousands of years. Early humans used fire to drive game, remove cover and remove obstacles to travel. For example, evidence suggests that fire-prone vegetation became more common in Australia with the arrival of humans about 40,000 years ago. The shaping of the forest-shrub-grass mixture in Australia goes far back into human pre-history and human impacts on forests are not simply a recent aberration.

The experience of Britain provides an interesting example. By 3000 B.C. Britain was almost entirely covered by virgin forests, which had recolonized Britain with continental tree species after the ending of the last ice age, some 10,000 years ago, which had scraped away any previous forest. Gradually, Bronze Age people in Britain cleared small areas of forest. The clearing accelerated with the arrival of the Celts about 400 B.C. and the rate of deforestation accelerated over the 400 years of Roman occupation ending in the 5th century A.D. Much of this early clearing in Britain, and indeed throughout Europe, was probably of the temporary slash-and-burn type common in tropical forests today.

Similarly, the forestlands surrounding the Mediterranean were reduced as farming expanded to feed a growing population. In addition, the Mediterranean forests contracted as they were used to provide fuel and materials for ship building and other construction. During the centuries, the forests of India and China (e.g. see Menzies 1992) also gradually shrunk. There were minimal differences in the scale of deforestation and landscape changes between feudal Europe and Imperial China (Turner II and Butzer 1992, p 19).

Over thousands of years not only did the forests contract, but the underlying ecosystems adapted to an environment that included the continuous and disturbing presence of humans. This was true not only in Europe, but in varying degrees in the forest/grasslands interface of Africa and throughout the native societies of what would become the "new world." One of the greatest obstacles to regeneration in the Mediterranean forests was the introduction of the goat, whose browsing behavior prevented forest regrowth. (Thirgood 1986).

Commercial logging is not a major cause of deforestation since temperate forests, which produce most of the world's timber, are essentially stable.

MEDIEVAL EUROPE

Central Europe completed conversion of large forest areas into agricultural lands during the 12th and 13th centuries. Ore smelting and glass making, whose development in central Europe began in the 14th century, relied on wood for energy. By the end of the 16th century, large portions of the Alps had been deforested to provide wood for blast furnaces. This was later followed by Alpine torrents and violent flooding (Santorius and Henle 1968).

The scarcity of ship timber at the end of the 18th century caused some European governments to promote tree planting. During the 19th century tree plantations became more common throughout Europe (e.g., see Johann 1990). Europe's forests were probably at their smallest extent more than a century ago (Thirgood 1989). European forest regrowth probably began about the middle of the 19th century. For example, figure 1 shows the expansion of the forest area in France since 1800.

FORESTS IN THE NEW WORLD

Although European explorers viewed the forests of the New World as essentially undisturbed by human activity, Turner II and Butzer (1992) note that: "In large part, the forest of the Americas, from Canada to Argentina, were ... highly disturbed or modified by Amerindian use by 1492..." (p. 37).

The pre-Colombian disturbances included shifting cultivation, forest culling, the use of fire and so forth. Large populations of indigenous peoples in the tropics suggest that major land use adaptations were required and there is evidence of large scale irrigation and substantial land clearing. In addition to human impacts, the forests were also buffeted and modified by disease, insect infestation, storms and wind as well as natural fire.

The settlement of the New World by Europeans began slowly. By the end of the first one-hundred years, only 175,000 Spaniards had colonized the Americas, and British colonization had not yet begun. The forests of eastern North America were impressive and gave rise to the view of a pristine wilderness. However, Turner II and Butzer (1992) point out that:

"In large part, the forest of the Americas, from Canada to Argentina, were highly disturbed or modified by Amerindian use by 1492."

Many of the primeval forests that were supposedly encountered by the Europeans and that remain today, including forests with higher biodiversity were not "pristine" or "virgin" but were the product of extensive use and modification by the Amerindians" (p. 42).

The frequent references of Europeans to "fields," "meadows," "openings" and so forth leave little doubt of the land clearing activities of native peoples (Williams 1990).

The destruction of large portions of the Amerindian populations, largely from diseases brought by the Europeans to which the local populations were highly susceptible (Denevan 1992), changed the character of the land occupancy in the Americas. This reduction of Amerindian populations by disease may ultimately have created the "wilderness" that awaited the arrival of European settlers.

In fact, Turner II and Butzer (1992) state that: "Deforestation in the Americas was probably greater before the Columbian encounter than it was for several centuries thereafter" (p. 42).

Thus European settlement did not disturb wild, virgin and pristine forests, but simply continued to modify forests that had experienced a minor respite after an extended period of intensive change by Amerindian cultures.

U.S. FORESTS

Forests covered 1,044 million acres, or about 40 percent of the land area of the United States, at the time of European colonization (MacCleery and Smith 1994). At first the impacts of Europeans on the native forests were modest. Early farming was small scale and low intensity with few permanent effects on forest vegetation. Land clearing was slow and often deforestation was not permanent. Williams (1990) notes that it was common for farmers to abandon depleted fields after a decade or two and move on to clear new forest. The abandoned fields would then regenerate forests naturally. Clawson (1979) estimates that by 1800 the amount of forestland conversion in the U.S. was "modest."

In many respects, the North American forests of the precolonial period were probably not so different from those of today.

New England, which was 90 to 95 percent forested at the advent of the colonists, experienced large declines in forest area. By 1850 the forests of Vermont, Rhode Island, Connecticut, Massachusetts covered only 35 percent of the land area. The forests of New Hampshire were reduced to 50 percent of the land area and 74 percent of Maine's land area (Barrett 1980). The forests of the mid-Atlantic states and the southern coastal areas also experienced significant forest reductions.

Nevertheless, Williams (1987) estimates that by 1850 "only" about 114 million acres of forest had been cleared since settlement, a period of over 200 years. Most of this was after 1800. This is not surprising since the population of the US, which was only 5.8 million in 1800, but had grown to 23.2 million by 1850. Large scale land clearing began in the eastern US only after the mid 1800s.

In many respects, the North American forests of the precolonial period were probably not so different from those of today. Pine dominated the southeastern states, and wildfires were frequent, both created by natural forces and by native peoples. The pine forest of the South gradually gave way to the deciduous forest of the north, which, in turn gave way to spruce and fir forests to the north and in eastern Canada.

Although old stands were undoubtedly common in colonial America, natural disturbances, including insect infestation, disease and fire, as well as the actions of the native peoples, probably limited their occurrence. For example, infestation, such as the spruce budworm, was common and tended to operate in long-term cycles rising for periods doing large amounts of damage and then receding for decades. Older stands tend to be more susceptible to both infestation and disease, thereby limiting the age of the stands. Also, weakened, diseased and infested stands were vulnerable to wildfire, as were stands damaged by hurricane, windstorms, and other natural forces. All these factors tended to reduce the longevity of forest timber stands.

In the arid west of the U.S., natural forces tended to place age limits on many of the forests. Fire was common in the dry areas that experienced periodic drought. Infestation too was common. In addition, periodic prairie fires, both natural and caused by the native peoples, tended to limit the extent of forest expansion. In fact,

recent studies indicate that the forest biomass in the northern Rocky Mountains is 30 percent greater than in the middle of the 18th century, just before Europeans arrived. The dramatic reduction of wildfire is believed to be a major factor in the build-up of forest biomass over the past several decades (Williams 1989).

Until the mid 1800s most forest clearing was done to open agricultural lands, and wood still provided 90 percent of the nation's energy output. However, after 1850 forest clearing accelerated to meet the growing industrial demand for wood. This period of large-scale forest clearing in America lasted a relatively short period — from about 1850 to 1910. Almost 50 million acres were cleared in the 1870s alone and perhaps 200 million acres cleared over the 60 year period (Williams 1989). Between 1870 and 1910, the huge forests

After 1920, U.S. forest area began a modest rebound as agricultural lands were abandoned.

of the Lake States were cut to supply the material requirements of rapid industrialization. Railroads also had huge appetite for wood. Forests were felled to supply cross-ties and bridges for the rapidly expanding rail system. Railroads consumed nearly 25 percent of the wood used in the 1800s (McCleery 1994).

Three hundred years after the arrival of Europeans, about 300 million acres of forests had been cleared in the United States. Fully two-thirds of the deforestation in the U.S. occurred in the 60 years prior 1910. Forests were reduced from 1,044 million acres, or about 40 percent of the total land area, in 1630 to 760 million acres, or about 30 percent of the land area in 1907. After 1920, U.S. forest area began a modest rebound as agricultural lands were abandoned.

By one measure, U.S. forests have unambiguously expanded since 1920. Six national timber inventories have been undertaken since 1952 with the latest one taking place in 1991. Each inventory showed a greater forest volume than the former inventory. U.S. forest biomass has increased despite timber harvests that have continued to provide the country with large volumes of wood over the past 75 years. The U.S. is still the world's major industrial wood producer, producing roughly 25 percent of the world's total.

The ability of American forests to both expand physically and to provide large volumes of timber is the result of a combination of factors. These include improved tree growing technologies, which lead to better forest management; the advent of tree plantations; and improved control of wildfire in the forest (see Sedjo 1991). As Clawson (1979) noted years ago, however, forest volume cannot rise indefinitely. Net growth is a sign of a young forest. At some point natural mortality will equal growth, even in the absence of any human involvement.

TROPICAL FORESTS IN THE AMERICAS AND ELSEWHERE

The image of pristine New World tropical forests undisturbed by humans is almost surely wrong. The Amerindian populations of Central and South America were substantial. Some 54 million Amerindians lived in the Western Hemisphere in 1492, over 50 million south of current U.S. boundaries (Denevan 1992). These populations considerably modified the natural environment. Terracing, irrigation, agroforestry and so forth were common, if not pervasive. An estimated 76 percent of the population of the Americas south of the present-day U.S. was eliminated between 1492 and 1650 (Denevan 1992). The overall effect was the drastic reduction of agriculture and the consequent afforestation of many tropical lowlands. Turner II and Butzer (1992) argue that "the scale of deforestation, or forest modification, in the American tropics has only recently begun to rival that undertaken prior to the Columbian encounter" (p 42).

In the tropics, as in the U.S., the 19th century saw a decrease in the area of forests largely due to pressures for increased agricultural lands. Logging in the tropics did not constitute a serious threat to the forest since the logging was typically selective, felling only a few trees in any area, the rate of logging was slow and regeneration typically occurred. In southern Brazil, the native peoples used fire to clear land for "slash-and-burn" cultivation. This practice was imitated and expanded by the Europeans and gradually gave way to more permanent conversion to pastures and croplands in the 20th century (Williams 1990). In Central America forests were cleared to grow coffee after 1830, bananas after the 1890s, cotton after the 1940s and cattle beginning in the late 1950s (Williams 1992). In the Philippines forest was cleared to grow sugar cane and rice, as well as for ranching (Roth 1983). In parts of India, forestland was cleared for cotton and tea production (Richards and McAlpin 1983; Tucker 1988). In Burma, land was cleared to increase rice production (Adas 1983); while in Thailand, both rice and rubber cultivation contributed to forest area reductions. (Feeny 1988).

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COMMERCIAL FORESTRY

Commercial forestry provides wood for processing into various commodities and products, but not for fuel. Industrial wood obtained from commercial harvests is grouped into two categories: solidwood and fiber. Solidwood refers to products such as lumber and wood panels. Fiber products initially referred to products such as woodpulp (an intermediate product) and paper products. In recent years the distinction has been clouded by the development of a number composite solidwood products manufactured from wood chips such as fiberboard and wafer board. Global timber production and consumption has increased only about 1 percent annually over the past two decades (Sedjo and Lyon 1991).

Table 1 presents the industrial wood production level by country for 1991. As can be seen, fully 73.6 percent of total production comes from temperate forests of the industrial countries of the northern hemisphere. Without exception the temperate countries that are supplying the vast majority of the world's industrial wood are the same countries in which the forest estate, both forestland area and forest stocks, has remained stable in recent years.

Another 9.3 percent comes from the plantation regions of Oceania, South America and South Africa. Although some of those countries are experiencing deforestation, as table 2 shows, for many of those countries most of domestic industrial wood production is provided by the plantation forests.

In all of the data presented, the countries provide a high fraction of their industrial wood from their plantation resources. Plantations have inherent advantages in terms of location, accessibility, wood type and wood quality. Natural forests no longer serve as a major source of industrial wood.

Although many environmentalists claim that commercial logging is a major cause of deforestation, most knowledgeable observers now recognize that commercial timber harvests generally do not involve the permanent conversion of land to another use. Rather, forestlands that are commercially harvested typically remain as forestlands. Reforestation occurs either through tree planting, or less commonly today, through natural regeneration. In recent years between 2.5 and 3.0 million acres (about 1.0-1.2 million hectares) have been planted annually in the U.S. (see figure 2). This amounts to the planting of 4-6 million seedlings *each day*. In addition, an estimated 4 million hectares of forest plantations are being established worldwide, much of it for commercial purposes.

Temperate forests provide about 75 percent of total world production of forest products. Meanwhile, the world's major temperate timber producers are not experiencing either reduced land area in forests or a reduction of their forest stocks. This means that the harvests are less than the forest regrowth. For example, figure 3 shows that, for the six forest inventories taken in the US since 1950, net forest growth exceeded harvests for all six. Thus, despite the US being the world's number-one timber producer, U.S. forests have continued to increase in volume.

The same is true for Russia and Canada, the wood producers ranked second and third in the world, as well as for western Europe, the collective production of which is significantly larger than that of Canada. Thus, although almost three-fourths of total world commercial timber production occurs in the northern temperate forests, these forests are expanding in both area and forest volume.

By contrast, only about 15 percent of the world's harvests occurs in the tropics, and even less of the total production is tropical timbers from natural forests, since much of the tropical production is from plantations.

The regions that are producing most of the world's commercial timber are also the regions whose forests are stable or expanding (the temperate region), while the region producing a relatively small fraction of total industrial wood production (the tropics), is the region that is experiencing significant deforestation.

The driving force behind tropical deforestation is clearly not commercial harvests. Tropical deforestation is driven primarily by desire for agricultural land.

FOREST RENEWAL AND PROTECTION

While much of the focus of public attention has been on deforestation, I have shown how many regions of the world are experiencing substantial reforestation. The resurgence of forests are the result of: 1) stabilized or increasing net forest area over vast regions of temperate forests, 2) increased cropping of industrial timber through forest plantations, 3) increased interest in agroforestry 4) increased reservation of forest areas for national parks, ecological reserves, and other protected status. (Laarman and Sedjo 1992).

Temperate forests provide about 75 percent of total world production of forest products.

Forests have an amazing capacity for renewal. This should not be surprising since forests have frequently been ravaged by nature since prehuman times. Fire, insects, disease, wind storms all can do great damage to forests. Furthermore, forests have also had to survive periodic ice ages and other climatic changes. The process of natural reforestation only awaits the opportunity. Reforestation began in parts of the eastern US as early as the mid 1800s, not as the outgrowth of a specific policy, but simply as the result of benign neglect due to the abandonment of the agricultural fields that had been chopped out of the native forest. Some farms began reverting to forests as early as the mid-19th century (Harper 1918). By the 1990s Vermont was 75 percent reforested; New Hampshire 86 percent; Connecticut, Massachusetts and Rhode Island almost 60 percent; and Maine about 90 percent (Barrett 1980, MacCleery). Similarly, the abandonment of depleted farmland in the South and the Lake States led to the reforestation of large areas of those regions. (see Hart 1968 and Williams 1989). Little of it required human intervention.

Areas where forests occur naturally and precipitation is plentiful, such as the eastern US, have little problem with natural forest regeneration. Under most circumstances, abandoned fields spontaneously begin to

regenerate, often in pine. In a period of a decade or two the forest is firmly reestablished. In New England these regenerated forests were commonly called “old field pines” reflecting the ability of pines to establish on “old fields.” Over time, the pines, which require abundant sun to grow are gradually replaced in the forest understory by more shade tolerant conifer species or by a hardwood forest, such as is common in much of New England today.

The former agricultural fields in the South also often tended to regenerate in pines, although hardwood regeneration is common on certain sites under various circumstances. Similarly, many of the former pinelands of the Lake States that were deforested and converted to agriculture, are now reforested in a variety of tree species, some often quite different from the earlier pine.

Reforestation is not unique to the U.S. Major forest regrowth began first in Europe whose forests are still undergoing the greatest degree of net reforestation in the world. Today, most of Europe is rather heavily forested (see figure 4).

Even tropical forests, often characterized as fragile and difficult to regenerate, usually will renew themselves if not impeded by alternative land uses. For example, much of the tropical forest of Central America was believed to be pristine, but now we know that this forest has overgrown early native civilizations that had severely disturbed it. Similarly, the banks of the Panama Canal, which were almost wholly defoliated during the construction of the canal, are now covered with lush tropical forests. This regeneration is due entirely to natural processes.

PROTECTED AREAS

The increase in the number of protected areas is one response to concerns over the losses of wilderness, wild and undisturbed areas, including forest. The areas under protected status have expanded rapidly in this decade and especially in recent years. Figure 5 shows the cumulative area under protected status since 1900. Although it took approximately sixty years, for the first 1 million square kilometers to achieve protected status, the second million took only about ten years. In the last reported fifteen years, almost 3 million additional square kilometers have been placed in protected status.

Table 3 presents an estimate of the extent of wild areas in the world by major region. This study identified global land areas with a minimum size of 400 thousand hectares having no roads, buildings, transport infrastructure, powerlines, pipelines, mines, dams, canals, aqueducts, reservoirs, or oil wells (McCloskey and Spalding 1989). This study revealed nearly 5 billion hectares of “wilderness” lands, about one-third of the global terrestrial area. Some 60 percent of the wilderness is tundra, deserts and similar lands. Forests of all types, but mainly cool coniferous forest and tropical moist forests, constitute another 30 percent or 1.5 billion hectares.

Although this estimate is clearly crude, it does suggest that very large portions of the earth’s terrestrial surface is unoccupied by humans and remains essentially in a wild condition, being minimally effected by human

The regions that are producing most of the world’s commercial timber are also the regions whose forests are stable or expanding.

Even tropical forests will renew themselves if not impeded by alternative land uses.

structures and direct disturbances. Additionally, a substantial portion of the earth's forest (perhaps forty percent of the total) is found in this wild area.

PLANTATIONS

Roughly two-thirds of the world plantation forests are located in the temperate forest area.

Reforestation can occur as a natural process via natural regeneration or it can be the result of conscious human efforts to promote forest growth through tree planting. Planting is usually undertaken to control which species grow on a site, to accelerate the reforestation process or to encourage forest growth where it would not occur naturally. Perhaps the first published reference to forest planting is found in the *Guanzi*, a fourth century B.C. Chinese manual on the art of government, which contains instructions and rules for timber planting, management and protection to ensure a continuous supply of wood (Menziess 1985). Forest plantations were established in the 14th century in Italy in the Florentine mountains and in the 15th century in England and Scotland. By the 17th century there are calls to plant trees in Germany, France and Britain. During the 19th century large areas of Europe were planted, largely in conifers, both for the timber values and to protect the valleys from catastrophic flooding and avalanches that resulted from earlier logging and livestock grazing on steep mountain sides (Thirgood 1989).

The latter part of the 20th century has seen a burgeoning of forest regeneration activity in much of the world. Evans (1986a) estimated plantations had attained an area of 120 to 140 million hectares by the mid-1980s.

In the tropical countries of Asia and South America especially, plantations are being established at an accelerating rate. In 1992, an FAO study also revealed that there were about 30.7 million hectares of plantation forests in the tropics and that the 1990 net increase was about 1.82 million hectares annually. This is a very sharp increase over the 11.876 million hectares of plantations in the tropical region reported by FAO for 1975 (Lanly and Clement 1979).

Table 4 provides the FAO estimates of plantation areas and annual planting rates in the tropics, while table 5 provides estimates of the size and annual level of planting of the top ten tropical countries.

Table 6 presents an estimate of the area of plantations in some non-tropical developing countries. As can be seen, China in particular has both a high number of plantations and a high annual rate of planting.

PLANTATIONS IN THE TEMPERATE REGIONS

Although plantation forests are increasingly important in the tropics, even more plantations are being established in the temperate countries. Postel and Heiss (1988) provide estimates of the extent of industrial plantation forests in 1985, including the U.S., U.S.S.R., western Europe, and Japan (see table 7). Roughly two-thirds of the world plantation forests are located in the temperate forest area.

In 1993, tree planting in the US occurred on almost exactly 1 million hectares (USDA 1994a). Although this is down from its 1988 peak of 1.37 million hectares (3.39 million acres) under the Conservation Reserve Program, the amount of tree planting is still impressive. The number of plantings in the U.S. was estimated for 1993 as 4 million trees *per day* each day of the year. This, it might be noted, is below the highest levels of 6 million trees planted *per day* experienced a few years earlier.

Taken in its totality, the portion of the total forestlands in plantations is continuing to increase, although the U.S. has maintained roughly the same area of forest over the last 75 years.

Globally, Pandey estimates about 4 million hectares of trees are planted annually. This compares with Mather's 1990 estimate of about 10 million hectares annually in the temperate region. Mather's number appears somewhat high. However, planting rates can vary. For example, New Zealand is currently planting about 100,000 hectares annually, well above the 10,000 reported for 1990 in the Pandey study (Sutton 1994).

Plantation forests are significant for a number of reasons. Conceptually, plantations represent an extension of the agricultural cropping model to forestry. No longer do humans forage from natural forests for their wood materials. As in agriculture where cropping replaces the gathering of food, forest plantations replace wood that would otherwise be harvested from natural forests.

GLOBAL FORESTS: THE CURRENT SITUATION

The precise amount of deforestation both worldwide and in the tropics is difficult to determine as is the precise amount of current forested area.

Plantations represent an extension of the agricultural cropping model to forestry.

TROPICAL FORESTS

The evidence indicates that the rate of conversion of the tropical forests has continued to increase. Tropical forests were estimated by the FAO(1993) to cover 1,910 million hectares in 1980. By 1990, tropical forest cover was reduced to 1,756 million hectares. Thus the average annual area of tropical deforestation amounted to 15.4 million hectares, or an 0.8 percent annual rate of deforestation over the decade (see table 8). This compares with the 1980 estimate of tropical deforestation at 11.3 million hectares annually or a 0.6 percent annual rate.

Tropical forests still cover over 13 percent of the global land area, or an area almost exactly that of South America. By ecological zone, 76 percent of the tropical rainforest zone is still covered with forest; 46 percent of the moist deciduous area, 30 percent of the dry deciduous and 19 percent of the dry and very dry zones taken together. (FAO 1993.)

TEMPERATE FORESTS

Temperate forests have not been as systematically examined as tropical forests. However, based on the ECE/FAO 1990 Assessment, Korotkov and Peck (1993) conclude that the area of forest in Europe increased, as did that of the former Soviet Union. The ECE/FAO Assessment concludes that the U.S. experienced a modest decline in forest area during the last decade (see Korotkov and Peck 1993), while Canada appears to be roughly in balance (Homer et al. 1990; ECE/FAO 1990).

Japan reestablished her depleted forests in the early post-war period with a vigorous program of reforestation. The Japanese forest area showed only very small decline over the past decade. Finally, although not part of the industrial world, in the past three decades China, basically a temperate climate country, has undertaken a massive and largely successful program of reforestation as has South Korea.

Thus, based on the ECE/FAO 1990 Assessment, Korotkov and Peck conclude that for temperate region countries as a whole there was a slight increase in the total forest area between 1980 and 1990. In the U.S.

the period of rapid deforestation was between 1850 and 1910, in the tropical world the period of rapid deforestation appears to be occurring now.

In the past three decades China has undertaken a massive and largely successful program of reforestation.

ACID RAIN AND FOREST DIEBACK

Other reports bolster the ECE/FAO reports on European forest regrowth. A recent study by the European Forestry Institute (Kuusela 1994) found that forests in Europe have been increasing substantially in total land area and forest volume since 1950.

Perhaps the most puzzling aspect of these findings was the large *increase*, about 35 percent, in the rate of forest growth that occurred during the 1980s. This surge in forest growth was occurring broadly throughout Europe at the same time as the highly popularized fears over forest dieback, allegedly being caused by acid rain, were peaking. Some environmentalists claimed that the sulfur dioxide released into the atmosphere as a result of burning coal to produce electricity was damaging forests when it was deposited with rainfall. The new findings contradict the notion that acid rain pollution had severe effects on European forests. Careful surveys of tree conditions in Europe did not find widespread damage as a result of acid rain (Kandler 1993). The scientific community now regards claims about the extent of damage to forests caused by acid rain, the "dieback theory," as having been refuted by the evidence (Kandler 1993).

The experience in the U.S. has been similar to that of Europe with respect to the effects of acid rain on forests. The \$600 million long-term National Acid Precipitation Assessment Program (1991) found little evidence that acid rain was causing significant damage to forests in the United States.

The effects of air pollution on forests are complex. Clearly, while intense exposure to sulfur dioxide can cause local damage, the damaging effects of acid rain have been widely exaggerated.

TOTAL GLOBAL FORESTS

The most recent EEC/FAO reports cited above estimate the current forested area at 2.06 million hectares in the industrial countries and 1.756 million in the tropics for a total of 3.82 million hectares. This number apparently excludes the temperate forests of northern China and Korea and so underestimates the world's total. A reasonable estimate of total world forested area currently is just a bit below 4 billion hectares.

Worldwide, about 77 percent of the global forest area is publicly owned, and 23 percent is private.

MARKETS, OWNERSHIP AND FORESTS

Worldwide, about 77 percent of the global forest area is publicly owned and 23 percent is private (FAO 1963), although some estimate that 90 percent of the world's forests are publicly owned (Steward 1985). Thus, whatever forests have suffered and what the future holds for them lies, to a large extent, in the hands of government.

This ownership pattern represents a combination of accident and design. In the U.S. for example, the lands to the west of the eastern seaboard were public lands. For decades, the policy of the U.S. was for these lands

to be privatized via the Homestead Act, transfers to railroads and so forth. Nevertheless, toward the end of the nineteenth century, as public concerns about the condition of the forests increased, large areas of unprivatized forestlands were placed into public reserves, most of which later became the lands of the National Forest system.

Similarly, large areas of forestlands in South America, Asia, Africa, Russia and Canada are state lands. Some countries promote privatization as a vehicle to frontier development, as in Brazil. Russia is considering long-term concession arrangements with private firms. But most countries are not moving toward privatization.

In Canada, for example, most of the forestlands, especially in the west, are "Crown" lands controlled by provincial governments. Most Canadian timber production comes from Crown lands under long-term (e.g., 20 year) concession agreements. Although flexibility exists in the agreements, penalties are assessed for nonperformance including failure to meet the harvest goals, as well as for harvests in excess of the targets.

Similar systems exist elsewhere. The Indonesian government awards 20 year concessions for harvesting state forestlands to private companies. In the tropics the harvests are almost always selective, rather than clear-cuts, and the concessionaire is responsible for reforestation of the harvested area. Typically the reforestation is in native tropical species; however plantations are also being established in some places.

In the U.S. the Forest Service normally holds competitive auctions for timber harvest rights. Harvest must be completed usually within three to five years. Payment is made to the Forest Service on the basis of the volumes and species harvested. Long-term management responsibility, however, resides with the Forest Service. In addition to timber, the Forest Service has responsibility for the production of multiple outputs, including wildlife, recreation, water quality, and so forth. In recent years, the role of the public lands in industrial wood production has declined dramatically while that of the private lands has expanded production, in part to fill the void left by public harvest declines.

Private forestlands in the U.S. and elsewhere have tended to focus on the production of timber and industrial wood. In recent years, private forest lands have accounted for about 85 percent of the total tree planting and seeding in the U.S. Many of the management innovations which have increased tree growing productivity substantially were developed and adopted by the private sector. Similarly, private forestlands are major wood suppliers in eastern Canada, the Nordic countries and throughout Europe, as well as plantation regions of South America, New Zealand and elsewhere.

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FACTORS AFFECTING THE RATE OF DEFORESTATION

First, the situation in the temperate regions is quite different from that of the tropical regions. The temperate forests have been essentially stable or expanding for the past several decades to several hundred years. By contrast, the tropical forests are still being reduced.

Second, deforestation remains largely the result of the development and expansion of agriculture. Land conversion from forests to agriculture appears to have largely ceased in the temperate world. In fact, reversion back to forests is more common. In the tropical world, however, the process of land conversion to agriculture continues.

Third, commercial logging is not a major cause of deforestation; expanding agriculture is. In temperate countries, which provide over three-fourths of the world's industrial wood, reforestation is the rule, while in tropical countries land conversion to agriculture remains common.

The developed countries in the temperate regions appear to have largely completed forestland conversion to agriculture and have achieved relative land use stability. By contrast, the developing countries in the tropics are still in a land conversion mode. This suggests that land conversion stability correlates strongly with successful economic development.

Countries that have achieved economic development almost always had an early period in which forestlands were rapidly converted to productive agricultural lands. Thus, conversion *per se* should not be taken as necessarily undesirable. Forested areas provided the agricultural land that allowed the development of Europe and North America.

Temperate forests are stable because developed countries have little incentive to expand their agricultural land base because they have dramatically increased crop yields on the acres already under cultivation (see Yamani and Ruttan 1971). By contrast, the developing countries crop yields are still quite low, which creates pressures to expand the areas under cultivation.

Additionally, industrialized countries have well developed institutions of land tenure, property rights, enforcement capabilities, judicial systems and so forth. Well-defined, secure property rights and markets provide clearer and less ambiguous signals. In the developing countries, deforestation has been exacerbated by the absence of clear property rights to the land and forest (Fortmann and Bruce 1988). In areas where large tropical forests exist, land ownership is often unclear and weakly held. Enforcement capacities are limited, judicial systems weak and so forth.

Weak or unclear land tenure encourages "slash and burn" agricultural systems in tropical forests. Insecure tenure limits the incentive to make long-term commitments to the land. So, peasant farmers quickly clear the land, make modest plantings, and abandon the site after only a few years. Since they do not own the land, peasant farmers have no incentive to engage in long-term activities, such as forestry, whose financial returns would exceed that of shorter-term agricultural activities. Therefore, the incentive structure is often "tilted" against forestry, even when the underlying situation is favorable.

Land conversion, from forests to agriculture, appears to have largely ceased in the temperate world.

In addition, governments often provide incentives for land conversion. In the 19th century U.S., the Homestead Act provided "free" title to public lands that were "improved" and "developed" and occupied for seven years. Land clearing was viewed as de facto evidence of improvement. Similar programs are often undertaken today in the developing world to encourage the development of "frontier" lands. In the late 1970s, 2 million hectares of tropical forest were cleared annually for cattle ranching in Latin America (WCMCS 1992). In many countries, converting tropical forests into pasture

was heavily subsidized. Governments also indirectly subsidized land clearing through extensive road construction, which provides low cost access to would-be farmers.

Further, deforestation can occur because traditional tenure arrangements break down, where the government lacks the power to enforce property rights and/or manage and protect public lands, or where the government

contributes to destabilization through perverse policies. Arnold and Campbell (1986) describe how the government of Nepal's nationalization of the forests generated destructive instability by alienating the local villagers. Infuriated villagers began to illegally log the forests that they had previously protected when they were communal property.

In summary, economic development promotes forest stability through:

- (1) well-defined and recognized property rights,
- (2) the enforcement of property rights,
- (3) the absence of government subsidies to encourage land clearing, and
- (4) high levels and growth rates of agricultural productivity.

CONCLUSION

Historically, humans everywhere have interacted with and "disturbed" the forest. As humans progressed and became agriculturists, rather than simple hunter-gatherers, they found it necessary to modify natural ecosystems. Land management tended toward replacing complex multi-species systems with ecologically simpler and more productive farming systems. In purely economic terms, the actual stock of forest lands exceeded the stock desired by humanity, while the actual stock of farm land was less than desired. This means that there were incentives for adjusting those stocks by converting forestlands into more highly desired agricultural lands.

However, this adjustment does not imply that the conversion trend will continue until all forests are gone. People have long recognized the value of forests, both as a source of construction materials and fuelwood and as a source of other forest outputs, e.g., game and recreation, and as a source of environmental services, e.g., watershed protection and flood control. The land conversion process is not one-way, flowing only from forests to cleared lands. Lands once cleared may be converted back into forests either as plantations or as naturally regenerated forests.

*Forests are not and
have never been
unchangeable.*

Forests are not and have never been unchangeable. Being biological systems they have an amazing resiliency and ability to adapt to fluid conditions, whether these changes are the result of nature or humans. Thus, although the forests of the temperate world have experienced many anthropogenic disturbances over the millennia, in many respects they are in remarkably good condition. In vast areas of the globe much of the natural forest is intact and minimally effected by human disturbances. In addition, plantation forests are growing in importance and increasingly deflecting timber harvesting pressures away from natural forests. It is likely that the world's forests will be stabilized early in the next century.

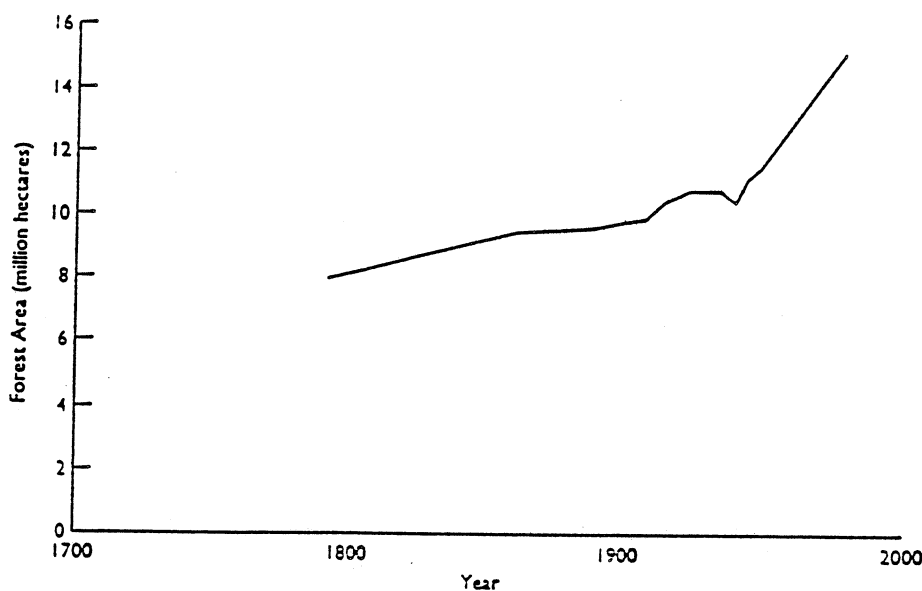
The first sentence in Marion Clawson's, *Forests for Whom and For What?* declares: "Forests serve the American people in many ways and have the potential to serve more people in better and more generous ways." This same insight can be expanded to include all of humanity and all the world's forests.

ABOUT THE AUTHOR

Roger A. Sedjo is a Senior Fellow and Director of the Forest Economics and Policy Program at Resources for the Future. He has considerable international experience, has written extensively on international forest issues and timber supply issues, and is author, co-author, or editor of several books, the most recent being *The Long Term Adequacy of World Timber Supply* (with Kenneth Lyon), *America's Renewable Resources: Past Trends and Current Challenges* (with Kenneth Frederick), and *Forests for a World of Six Billion People* (with Jan Laarman).

Tables and Figures

Figure 1



Expansion of Forest Area in France Since the Late Eighteenth Century.

Source: Walter V. Reid and Kenton R. Miller, *Keeping Options Alive: The Scientific Basis for Conserving Biodiversity* (Washington, D.C.: World Resource Institute, 1993), p. 73.

Table 1

Country	Production	Percent	Cumulative percent
USA	409.9	25.6	25.6
Former USSR	274.3	17.1	42.7
Europe, excluding Nordic countries	195.6	12.5	55.2
Canada	171.2	11.0	66.2
Nordic	88.4	5.6	71.8
Japan	27.9	1.8	73.6
China	90.0	5.7	79.3
Argentina, Chile			
Brazil, S. Africa	101.7	6.5	85.8
Malaysia, Indonesia, Philippines	76.9	4.9	90.7
NZ and Australia	42.9	2.8	93.5
Other	104.2	6.5	100.0

Global Industrial Wood Production: 1991 (million cubic meters).

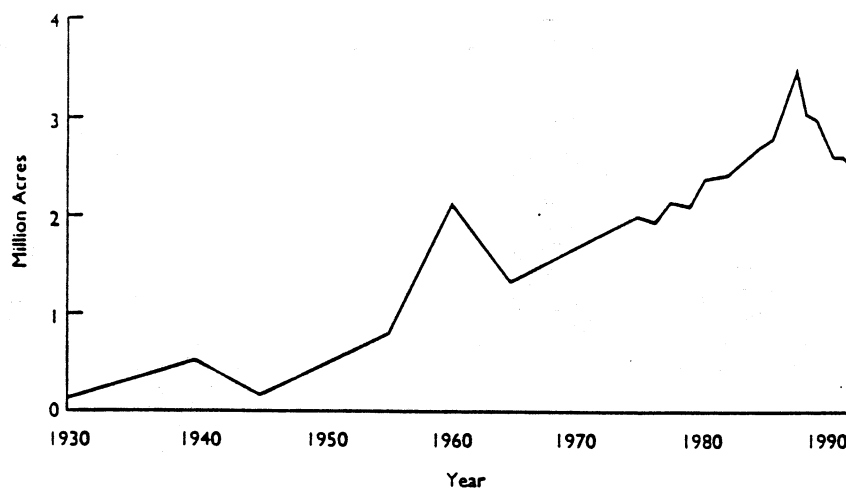
Source: *Forests Products 1980-1991*, FAO Yearbook. Rome, 1993

Table 2

	Total Area (thousand hectares)		Share of Plantations (%)	
	<i>Natural Forests</i>	<i>Plantations</i>	<i>Total Forest Area</i>	<i>Total Industrial Wood Production</i>
New Zealand	6,270	1,240	19	93
Brazil	396,000	6,500	2	60
Chile	6,300	1,400	22	95
Argentina	36,000	800	2	60
Zimbabwe	28,800	117	0.4	50
Zambia	12,900	60	0.4	50

Countries Providing a Large Portion of Their Industrial Wood From Plantation Sources.

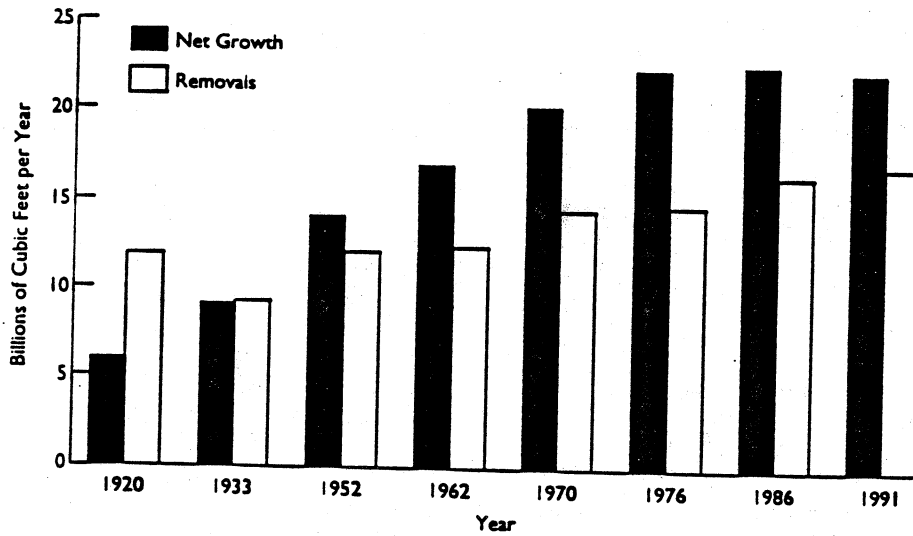
Source: Devendra Pandey, Assessment of Tropical Forest Plantation Resources, Swedish University of Agricultural Sciences, Department of Forest Survey, October 1992.

Figure 2

Tree Planting in the US, 1930-1993.

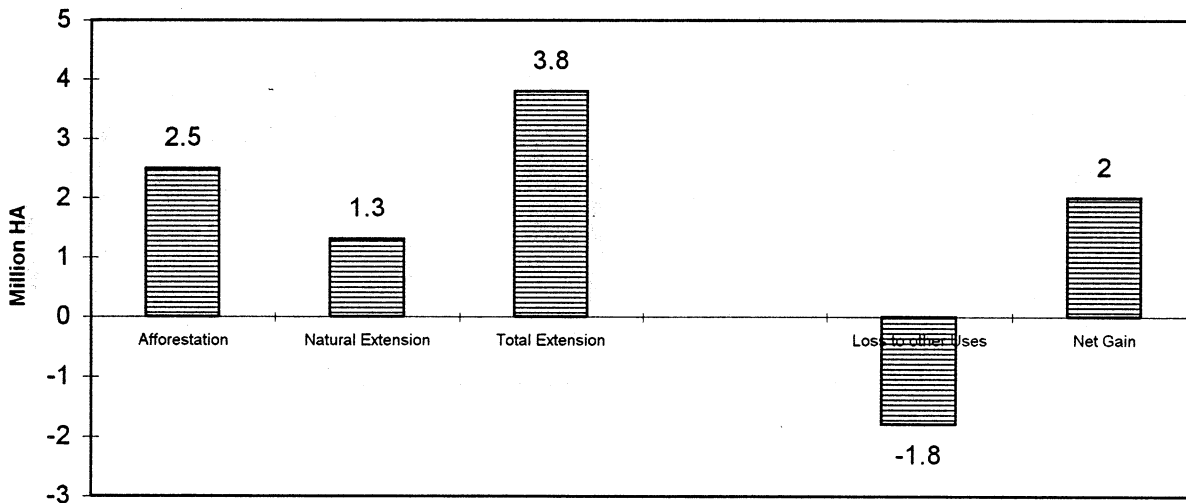
Source: (USDA FS 1993).

Figure 3



U.S. Timber Growth & Removals, 1920-1991.
 Source: Unpublished data provided by Douglas McCleery of the U. S. Forest Service.

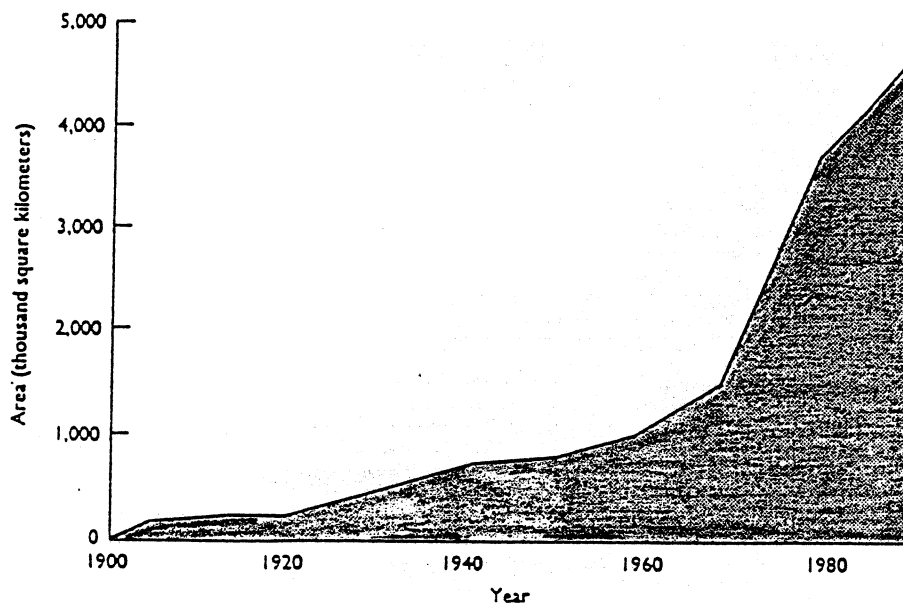
Figure 4



Estimated changes in the area of Europe's forest and other wood land between 1980 and 1990.

Source: Kov and Peck, *Unasylva*, vol 44, no. 174. P 24.

Figure 5



Cumulative world area under protected status since 1900.

Source: Reid and Miller 1989, p 71.

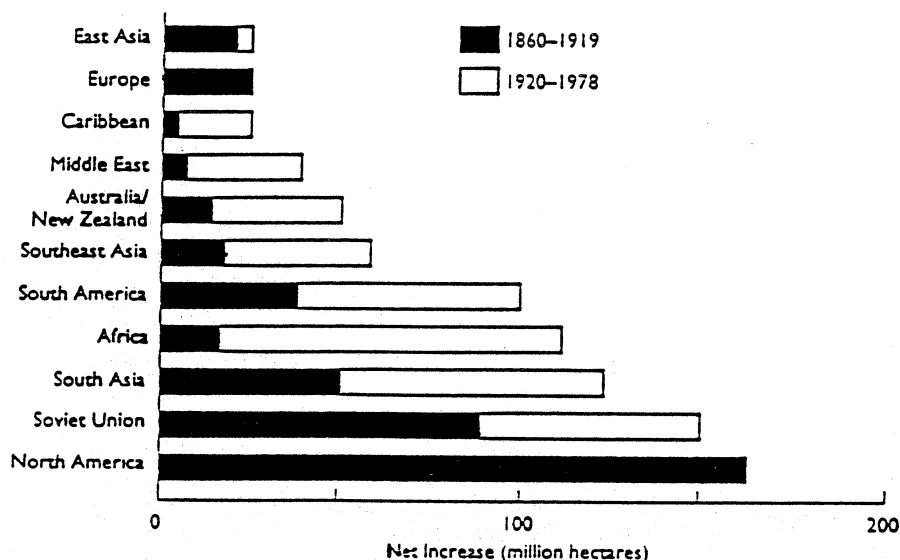
Table 3

	"Wild Area" (thousand km ²)	As Proportion of Total Land (%)
Antarctica	13,210	100
Africa	8,230	27
Soviet Union	7,520	34
North America	6,850	37
Asia (excluding Soviet Union)	3,780	14
Latin America	3,750	21
Australia and Oceania	2,370	28
Greenland	2,170	99
Europe (excluding Soviet Union and Greenland)	140	3
World	48,020	32

Extent of wild areas in the world by major region.

Source: "A reconnaissance-level inventory of the amount of wilderness remaining in the world," *Ambio* 18(4): 221-227. (1989) J.M. McCloskey and H. Spalding.

Figure 6



Expansion of World Land Areas Under Regular Cropping, 1860-1978.

Source: John F. Richards "World Environmental History and Economic Development," in W. C. Clark and R. E. Munn, eds., *Sustainable Development of the Biosphere* (Cambridge University Press, 1986).

Table 4

Region	Net Establishment	Net Plantings*
Africa	2,100	90
Asia & Pacific	22,600	1,470
Latin America & Caribbean	6,000	260

Net Forest Plantation Areas in the Tropics at 1990 (thousands of hectares).

*Net makes adjustment for mortality and other losses.

Source: FAO (1993) P 56

Table 5

Countries	Total	Annual
India	18,900	1,700
Indonesia	8,750	100
Brazil	7,000	200
Vietnam	2,100	125
Thailand	775	40
Venezuela	362	30
Cuba	350	30
Bangladesh	335	10
Myanmar	334.8	40
Madagascar	310	5

Tropical Plantations, Top Ten Countries, 1992 (thousands of hectares).

Source: Pandey, Assessment, p 15.

Table 6

Nontropical Developing Countries			Developed Countries		
<i>Countries</i>	<i>Total</i>	<i>Annual</i>	<i>Countries</i>	<i>Total</i>	<i>Annual</i>
China	36,000	1,250	United States	31,850	1,000
Republic of Korea	2,000	50	Undivided		
			Soviet Union	23,800	1,000
Chile	1,450	80	Japan	10,670	50
Republic of					
South Africa	1,333	30	Canada	5,023	400
Argentina	800	25	New Zealand	1,240	10
Morocco	526	30	Australia	965	30
Uruguay	208	2			

Forest Plantations in Non-Tropical Developing Countries, and Developed Countries, 1990.

Source: Pandey, Assessment, p. 19.

Table 7

	Plantation Area (thousands of Hectares)
<i>Industrialized Countries</i>	
Soviet Union	21,900
Western Europe	13,000
United States	12,100
Japan	9,600
Canada	1,500
New Zealand	1,100
Australia	800
Subtotal	60,000
<i>Developing Countries</i>	
China	12,700
Brazil	6,100
India	3,100
Indonesia	2,600
Republic of Korea	2,000
Chile	1,200
Argentina	800
Others	7,400
Subtotal	35,900

Global area of plantation forests circa 1985.

Source: Sandra Postel and Lori Heiss, *Reforesting the Earth*, Worldwatch Paper 83, April 1988, p. 28.

Table 8

Geographic Subregion/ Region	Number of Countries	Land Area			Forest Cover Million Hectares	Annual Deforestation, 1981-1990 % per Annum
			1980	1990		
<i>Africa</i>	40	2,236.1	568.6	527.6	4.1	0.7
West Sahelian Africa	6	528.0	43.7	40.8	0.3	0.7
East Sahelian Africa	9	489.7	71.4	65.5	0.6	0.9
West Africa	8	203.8	61.5	55.6	0.6	1.0
Central Africa	6	398.3	215.5	204.1	1.1	0.5
Tropical Southern Africa	10	558.1	159.3	145.9	1.3	0.9
Insular Africa	1	58.2	17.1	15.8	0.1	0.8
<i>Asia and Pacific</i>	17	892.1	349.6	310.6	3.9	1.2
South Asia	6	412.2	69.4	63.9	0.6	0.8
Continental						
Southeast Asia	5	190.2	88.4	75.2	1.3	1.6
Insular Southeast Asia	5	244.4	154.7	135.4	1.9	1.3
Pacific	1	45.3	37.1	36.0	0.1	0.3
<i>Latin America and Caribbean</i>	33	1,650.1	992.2	918.1	7.4	0.8
Central America and Mexico	7	239.6	79.2	68.1	1.1	1.5
Caribbean	19	69.0	48.3	47.1	0.1	0.3
Tropical South America	7	1,341.6	864.6	802.9	6.2	0.7
Total	90	4,778.3	1,910.4	1,756.3	15.4	0.8

Tropical Deforestation Rates, 1990.

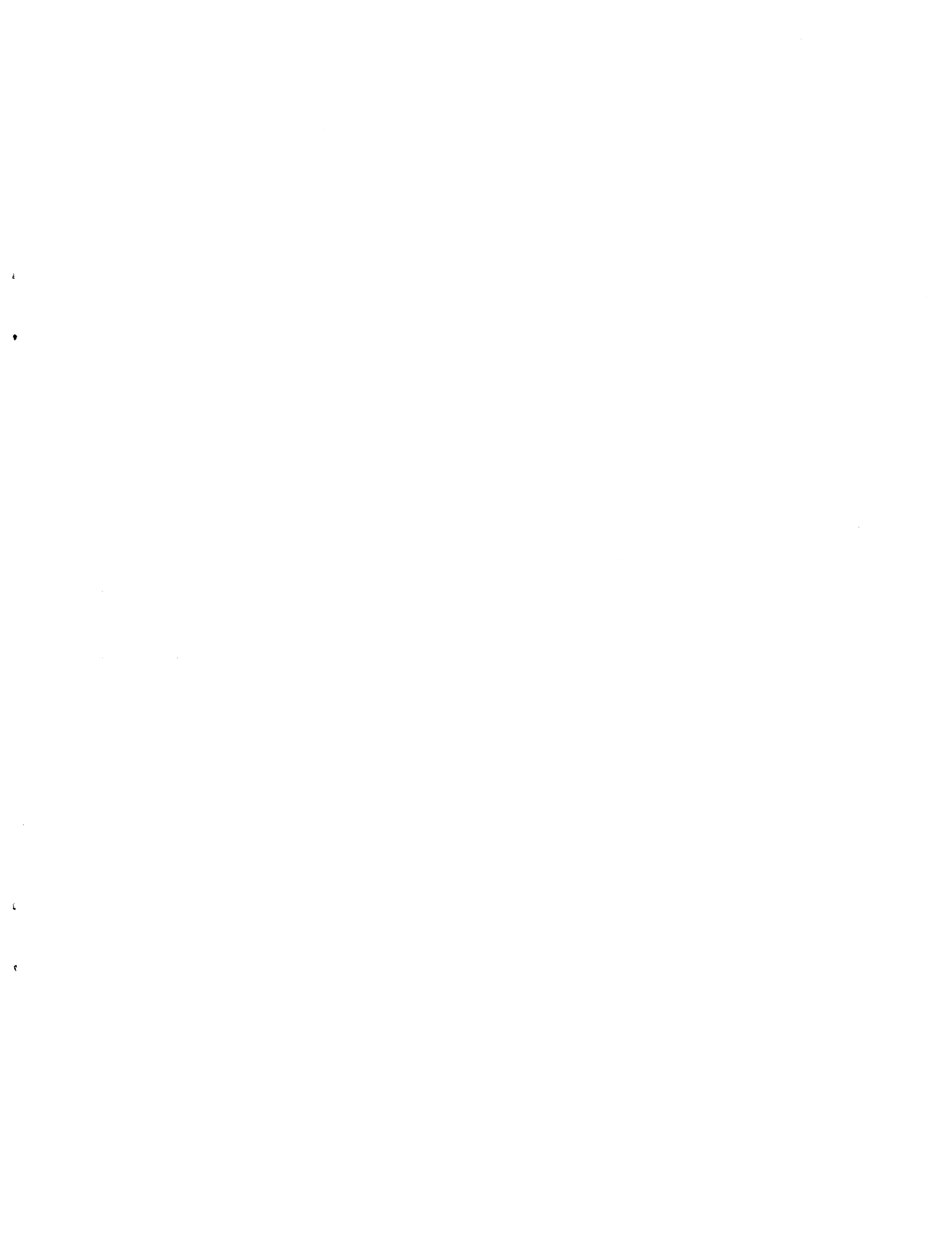
Source: Forest Resources Assessment 1990: Tropical Countries, FAO Forestry Paper 112, p. 56, Rome 1993.

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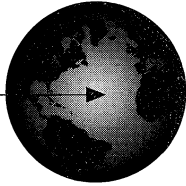
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