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The Kyoto Protocol and Forestry Practices in the United States

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Abstract

Forestry may play an important if not critical role in the ability of the U.S. to meet its greenhouse gas emissions target under the terms of the Kyoto Protocol. Given the low rate of change in the U.S. forest land area, the major anthropogenic influences on the current net forest carbon flux are forest management and protection activities that have resulted in continuing increases in forest carbon storage. Natural disturbances such as fire, insects, and diseases are locally important factors, but when all U.S. forests are considered, they are small relative to the effects of harvesting and growth. Carbon in U.S. forest ecosystems, wood products, and landfill wood was estimated to account for an annual net sequestration of about 300 TgC/yr during the 1980's, and are projected to comprise at least 200 TgC/yr over the next several decades. Proposed accounting rules under the Kyoto Protocol article 3.3 may render most of this C sequestration unaccountable towards the U.S. emission reduction target unless additional activities are accepted under article 3.4. Forestry practices that are likely to result in a positive C sequestration in the U.S. include afforestation of marginal cropland and pasture, improved forest management, adjustments in harvest timing, establishment of short-rotation biomass plantations, improved utilization of harvested biomass, and tree planting in urban and suburban areas.

Keywords: Kyoto Protocol, forestry, carbon sequestration

Introduction

The United States signed the Kyoto Protocol[1] on November 12, 1998, reaffirming America's commitment to meeting our most profound environmental challenge -- global climate change. Under the terms of the Protocol, the U.S. must reduce net emissions 7 percent below 1990 levels by the first reporting period, 2008-2012. This reduction is substantial given that emissions are expected to rise during this period due to population growth and economic expansion.

The role of forestry and land use change has been controversial throughout the international negotiation process. There are differing opinions around the world on whether forestry activities should be counted. A country’s position depends on factors such as whether its forests are currently or prospectively a net source or sink for carbon dioxide (CO_2), whether carbon (C) stock changes in forests can be measured and verified, and the relative emphasis that should be placed on reducing emissions versus increasing sequestration. Some countries express concern that forest responses to “natural” factors such as increased atmospheric CO_2 (which may increase growth) would allow a country to claim credit for greenhouse gas reductions that are not associated with specific activities.

The Kyoto Protocol attempted to reconcile the diversity of viewpoints on land use change and forestry. According to Article 3.3 of the Protocol, land-use change and forestry activities that can be counted toward the emissions reduction target include afforestation, reforestation, and deforestation since 1990 if the changes in stocks can be verified. Some interpretations of the definitions of terms under article 3.3 exclude managed forests with harvest and regeneration cycles from counting toward the emissions reduction target. However, article 3.4 provides an opportunity for nations to propose including additional activities such as forest management, and the agreement does include sustainable forest management as part of a general statement supporting sustainable

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[1] http://www.unfccc.de/resource/protintr.html for the full text of the Protocol.

development and protection and enhancement of sinks.

The language, terminology, and accounting methods contained in the agreement are somewhat vague, and can be interpreted in different ways. Definitions of key terms such as reforestation are not stated, which becomes a problem for implementation of the Protocol because there are many different definitions in use throughout the world (Lund 1999). The proposed accounting system is vague. For example, it is not clear whether harvested timber should be counted as a forest sink and if so, under which circumstances it could be counted.

To address these issues, the United Nations Framework Convention on Climate Change (UNFCCC) asked the Intergovermental Panel on Climate Change (IPCC) to establish an expert panel to develop a special report on the land use change and forestry provisions of the Kyoto Protocol. The panel is reviewing definitions, accounting issues, and activities that could potentially be included within the terms of the Protocol, and will document the various options for eventual reconciliation during the ongoing Conferences of Parties. This paper reviews the status and trends in U.S. forests as revealed by long-term monitoring, and explores the potential to increase carbon storage in forests as a contribution to the emissions reduction requirements of the Kyoto Protocol.

Trends in U.S. Forest Resource Statistics

The area of forest land in the U.S. has not changed significantly since the early 1900's. The area of forest land in 1907 is estimated as 307 million hectares, and in 1997 the area of forest land is estimated as 302 million hectares (*from preliminary statistics of the 1997 Resources Planning Act Assessment*). However, changes for the whole U.S. mask divergent regional trends. For historic and physiographic reasons, we speak of four regions in the U.S.: the North, South, Rocky Mountains, and Pacific Coast (Fig. 1). Since the 1900's, the North has been gaining forest land area, with the other three regions each losing forest land area (Fig 2). There have been significant shifts between land use categories, such that gains in forest land area from afforestation of agricultural land approximately offset losses of forest land area to development. There has also been a significant shift from natural forests to planted forests. The area of plantations in 1997, mostly in the South, is approximately 33 million hectares, or 11 percent of the total forest land area.

Figure 1. Regions used in the analysis

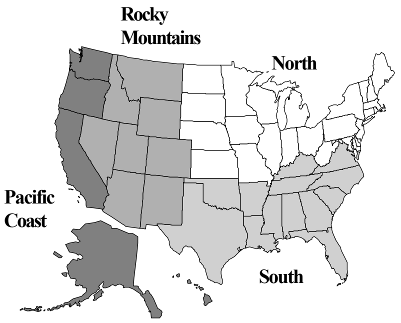
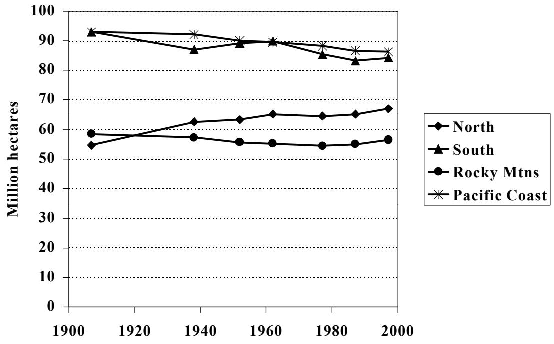
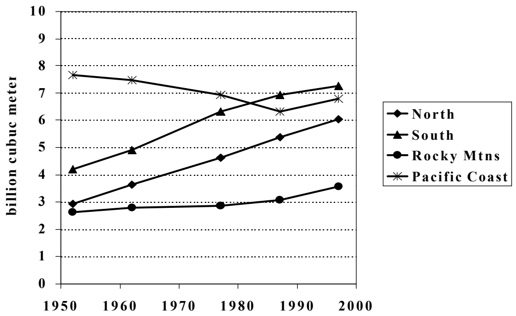


Figure 2. Forest land area in the U.S. by region, 1907-1997 (from Review Draft, 1997 RPA Assessment of the Nation's Forests)



The net volume of softwood growing stock increased by 12 percent between 1952 and 1997 to a total of 14 billion cubic meters. During the same period, the net volume of hardwood growing stock increased by 90 percent to 10 billion cubic meters. As is the case with forest land area, these changes differ by regions. The North, South, and Rocky Mountains each gained growing stock volume, while the Pacific Coast lost growing stock volume (Fig. 3).

Figure 3. Volume of growing stock in the U.S. by region, 1952-1997 (from Review Draft, 1997 RPA Assessment of Nation's Forests).



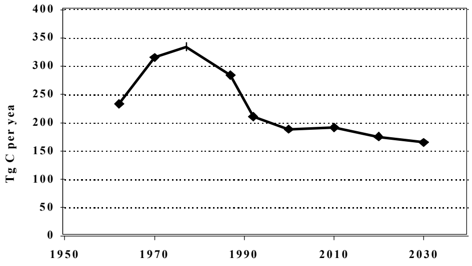
Differences in forest land area and growing stock volume trends reflect long-term changes in land use and harvesting. Millions of hectares of forests in the North, particularly in the Northeast, have regrown on agricultural land that was abandoned to forest land prior to 1900, causing a long-term increase in growing stock volume. These regrowing forests are now maturing, and therefore the rate of increase in growing stock volume is expected to slow substantially. The historical pattern is similar in the South, but the intensive utilization of southern forests for wood products over the last few decades has effectively halted regional gains in growing stock volume, as growth and removals have come into rough balance. Forest land area has not changed much in the Rocky Mountain region, where removals have been low relative to growth. Fire suppression and low removals have caused a substantial buildup of growing stock volume, and a corresponding increase in the potential for catastrophic wildfire in the region. In the Pacific Coast, growing stock volume has declined as old-growth forests have been harvested and converted to young regrowth. Growing stock volume is expected to continue the recent increase as more area of forest land has been reserved from timber harvesting operations.

Trends in Carbon Storage of U.S. Forests And Wood Products Under

A Comprehensive Accounting System

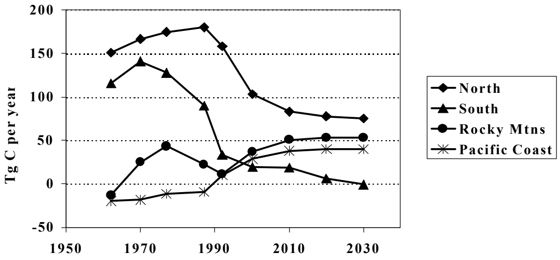
Forest inventory statistics can be converted to estimates of ecosystem C using known relationships between volume and mass for different species and regions. Ecosystem C pools are usually separated into several components: above- and below-ground live biomass, coarse woody debris, litter, and soil organic matter. Estimates of ecosystem C show that increases in biomass and organic matter in U.S. forests from 1952 to 1992 added 281 Teragrams of carbon per year (TgC/yr) to forest ecosystems, enough to offset 25 percent of U.S. emissions of CO_2 for the period (Birdsey and Heath 1995). Baseline projections using the U.S. carbon budget model FORCARB show additional increases of approximately 177 TgC/yr in forest ecosystems through 2040 (Fig. 4). This "baseline" carbon budget refers to long-term trends in forest carbon storage using economic assumptions from the 1993 RPA Assessment (Haynes et al. 1995), in the absence of major forestry policy changes or changes in forest productivity or species distributions as a consequence of climate change. The projected baseline includes forest policies in effect at the time the projections were made; in particular, reduced harvest levels on National Forest lands, decreases in clearcutting and increases in partial cutting practices, and continuation of federal cost-share programs at recent historical levels.

Figure 4. Past and projected carbon sequestration in U.S. forest (from Birdsey and Heath 1995)



There are significant regional differences in historical estimates and projected C storage in forest ecosystems (Fig. 5). These differences reflect the influence of many factors including variations in species composition and natural growth rates, and long-term changes in land use, management intensity, and harvesting practices as described earlier. A negative number indicates more carbon is being emitted to the atmosphere than being sequestered into forests.

Figure 5. Past and projected carbon sequestration in U.S. forests by region (from Birdsey and Heath 1995)



The amount of carbon in forests that are harvested and re-grown underestimates the total carbon sequestered in the forest sector. The amount of carbon sequestered in wood products and landfills is in long-term storage, and continues to increase because removals are projected to increase. Heath et al. (1996) estimated that by 1990, about 3,600 Tg of the 10,700 TgC removed from U.S. forests since 1900 remained sequestered in products and landfills. The quantity of C sequestered in wood products and landfills is increasing at about 37 TgC/yr, equivalent to 40 percent of the annual increase in forest biomass.

Possible Trends in Carbon Storage of U.S. Forests Under Article 3.3

Article 3.3 of the Kyoto Protocol states that only verifiable C changes due to afforestation, reforestation, and deforestation activities since 1990 may be credited or debited as part of a country's emissions reduction target. The trends in C storage will depend greatly on the adopted definitions of these activities. For example, under a narrow interpretation of the definition of reforestation, the only land on which carbon changes would count is land that changed use between forest and nonforest categories. This is projected to be a very small quantity of C in the first reporting period (2008-2012) based on area change data. Table 1 displays an estimate of gains and losses in forest land, calculated on an average annual basis (personal communication, Bryan C. Murray, and U.S. Department of Agriculture, Natural Resources Conservation Service 1996).

The estimated total non-Federal forestland area in 1982 was 162,296,000 ha. Thus, the annual gain in forest area is approximately 0.37% of the total forest area base, and the annual loss in forest area is even smaller. If these trends continue, approximately 10,890 hectares will be considered area increases in forest use by 2008, which is about 6% of the total forest area in 1990. Although the losses and gains are fairly close in absolute magnitude, the changes in C storage will be quite different because much of the area loss is to the land use categories of developed and miscellaneous uses. Land use changes to development are often more of a reclassification based on use rather than loss of tree cover. The net result of reclassification generally has very little effect on terrestrial C storage.

It is also unclear how deforestation will be counted in the future (Heath and Smith, 2000).

Carbon will be emitted as forest becomes cropland, but after a number of years, the farmer may switch to "no-till" practices that sequester C as compared to traditional tillage practices, or perhaps the land may revert to forest use again. In other words, the deforestation may be afforested. Keeping track of these possibilities may be confusing.

Under a different interpretation of article 3.3 definitions, changes in carbon stocks on a much greater area of forest land would be counted during the period 2008-2012. A common definition of reforestation includes land areas that were previously classified as forest, but were disturbed or harvested and are being re-grown as forest. Forests in the U.S., particularly the South, are actively managed, and this interpretation would therefore result in a much greater area on which carbon changes would be counted during the first reporting period. However, even this area would be substantially less than the total forest land area of the U.S. because only part of the forest land area would be disturbed or harvested between 1990 and the first reporting period.

Management Practices to Increase Carbon Sequestration

Article 3.4 of the Kyoto Protocol allows countries to propose additional activities that could be credited toward emissions reduction targets. Several categories of management practices that could have a positive carbon sequestration benefit in the U.S. are reviewed below. Not all have been studied thoroughly, but where possible, estimates of the gains in C storage are presented (summarized from Birdsey et al. 2000).

Afforestation of Marginal Cropland and Pasture

Many studies have estimated potential gains in C storage from afforestation in the U.S. A few examples are reviewed here. Moulton and Richards (1990) estimated that offsetting U.S. emissions by 10 percent (about 160 TgC/yr) would require about 29 million ha at an average cost of $12 million per TgC or $1.7 billion per year. Parks and Hardie (1995) estimated that converting 9 million ha of land to forest would increase C accumulation by 44 TgC/yr and cost $21 million per TgC. These two studies did not include effects of increased supply of timber on the forest sector, which may partially offset C gains by reducing prices and increasing demand. Parks and Hardie (1992) used FORCARB and forest sector models to develop two reforestation scenarios and compared the results with a base run (Heath and Birdsey 1993; U.S. Environmental Protection Agency 1995).

The average annual increase in C flux (including C in wood products and landfills) over a 50-yr period is projected to be 14.3 TgC for a 0.5 million ha/yr program costing $220 million/yr, or approximately $15 million per TgC. These costs include only the direct costs associated with tree planting and payment of subsidies.

Table 1. Estimates of changes in forest land use between 1982 and 1992 (1000 ha/yr). Federal ownership is not included.

Type of forest change:	Cropland	Pastureland	Rangeland	Developed and miscellaneous	Water	Total
Loss to--	59.9	116.9	46.5	281.6	19.1	524.0
Gain from--	129.5	337.6	62.8	67.8	7.5	605.2

Projections using a forest/agriculture sector model (FASOM) suggest that efforts to expand forest C flux should have a rather different geographic and species focus than that proposed in past studies (Adams et al. 1999). In contrast to both Moulton and Richards (1990) and Parks and Hardie (1995), FASOM projections suggest a greater emphasis on hardwood species in minimum cost strategies. FASOM simulations indicate that the bulk of the projected afforestation and management changes should occur in the North, mostly in the Lake States region. This is an area of large concentrations of hardwood forests in which hardwood stands can yield significant rates of C uptake. Although the FASOM model recognizes the rapid growth potential of afforested stands in the South just as in previous studies, broader measures of costs and inclusion of welfare trade-offs across markets and regions act to shift the minimum cost solution away from the customary prescription of pine plantations on marginal Southern agricultural lands. In reality, all of the land considered in these studies that could support trees may not be available. Even if the land were available, the infrastructure may not be in place to provide seedlings and assure regeneration for all available land. Additional technical assistance must also be provided to landowners for the planting programs to be effective.

Improved Forest Management

Timberland in the United States amounts to 198 million hectares (66% of the total forest land area) and includes a diversity of ownership objectives, forest types, site productivities, and stand conditions (Powell and others 1994). There are opportunities to sequester additional C on some portions of this large area of forest. Of particular interest are opportunities to increase the density of trees on non-stocked or poorly stocked forestland, and to apply silvicultural treatments to stocked forestland so as to increase the average biomass per unit area. Forest management practices in the U.S. to increase C accumulation may include: (1) restoration of poorly stocked forestland by clearing and regenerating if current productivity is well below average, (2) application of intermediate stand treatments (thinning or timber stand improvement) if the current stand is overstocked, and (3) management for longer rotation lengths (Birdsey 1992b). Including the value of C along with the value of timber increases the optimal economic rotation (Plantinga and Birdsey 1994; van Kooten et al. 1995).

Many silvicultural practices are designed to increase the production of growing-stock volume in desirable species. Gains in C storage are not necessarily proportional to gains in growing-stock volume because: (1) unmerchantable trees will also accumulate C, (2) stocking will increase naturally in poorly stocked stands, and (3) some management practices may remove biomass or disturb the site, resulting in loss of stored C. Studies have shown that thinning, for example, reduces total C storage compared with unthinned plantations (Dewar and Cannell 1992). Nevertheless, intensive forest management can increase total C accumulation over time relative to unmanaged forests, especially if the additions to wood product and landfill pools are counted. Row (1996) presented several case studies illustrating the potential gains from intensive forest management. Loblolly pine (*Pinus taeda*) plantations that are 30 years old contain on average 87 percent more C than natural stands on comparable sites. Gains of more than 100 percent over natural stands are possible with intensive management and genetically improved planting stock. Similar gains were found from converting natural aspen-birch forests in the Lake States to red pine (*Pinus resinosa*) plantations. Vasievich and Alig (1996) estimated that implementing economic opportunities on 82 million hectares of timberland could yield gains in C storage of approximately 140 Tg C/yr in vegetation, wood products, and offset fossil fuel C.

Conversion of mature or old-growth forest to young forest, which may have a faster growth rate, will reduce C storage until the harvested C remaining in products and landfills, plus additional C in the forest ecosystem from renewed growth, reaches the pre-harvest level. This may take 200 years or more in the case of old growth forest (Harmon et al. 1990), depending on site productivity and on how wood burned for energy is accounted for. Marland and others (1997) analyzed the effects of forest management on C in forest ecosystems, wood products, energy substitution, and product substitution. Results of their model (GORCAM) suggest that over long time periods, sustainable management for forest products on highly productive sites will yield a larger C offset than simply protecting the forests intact. They note the difficulty of estimating the magnitude of the substitution effects, and of attributing the C offset to particular projects because the indirect effects of any given project are spread widely and are likely to be partly claimed as a credit elsewhere.

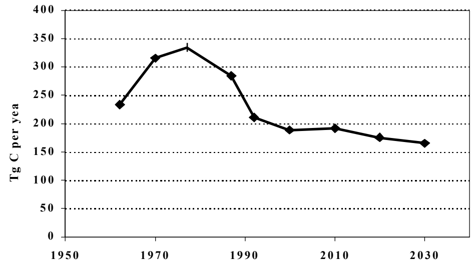
Adjustments in Harvest Timing

Reducing the area harvested can cause an immediate short-term increase in the amount of C stored in forests because losses of C to the atmosphere during the removal of biomass and processing are avoided. On average, only about half of the live biomass is removed from the site, while logging debris (leaves, twigs, branches), stumps, roots, and unmerchantable biomass is left behind to decompose, transfer to another C pool (e.g. litter or soil), or become part of the new stand of trees (Birdsey 1992a). Of the biomass that is removed, about 35 percent ends up in durable products or landfills (based on removals since 1900 and historical patterns of utilization and disposal), while the remainder is burned for energy or emitted to the atmosphere (Heath and others 1996, Skog and Nicholson 1998). Combining the estimates of on-site and off-site losses, only about 20 percent of the forest biomass ends up in long-term storage after harvest, and the remainder may be emitted to the atmosphere. Avoiding this loss by reducing harvest can be a short-term strategy to sequester additional C; however, over the long term, a continuous cycle of harvest, efficient utilization of biomass, and regrowth can sequester more C than not harvesting since the accumulation of C in the forest will eventually slow or stop, while it is possible to accumulate C in wood product and landfill pools for a very long time (Row 1996).

The effects of reduced harvest on C storage are evident in the estimated past and prospective C flux for National Forest lands (Fig. 6, Birdsey and Heath 1995). High rates of harvesting in the 1970-1990 period caused emissions of 50 Tg C/yr or more, while the significantly reduced harvest of the 1990's, if sustained, will cause a prolonged addition of C to National Forest lands, more than 80 Tg C/yr. In the unlikely event that all harvesting were stopped in the U.S., public and private timberlands could sequester an additional 328 Tg C/yr over a 50-year projection (Heath and others 1993).

Reduced harvest in one ownership category or region may be offset by increased harvest elsewhere, by substitution of energy-intensive non-wood products for wood products, or by changes in wood processing technology. Depending on the exact response, apparent gains in overall C storage may be lessened. The U.S. Environmental Protection Agency (1995) concluded that reducing National Forest harvest by 21 percent would be fully offset by increased harvest from private timberlands and increased imports. Adams and others (1996) concluded that reduced harvest on public lands in the West could be largely offset by substantial private forest investment and increased harvest on private lands in the South. Martin and Darr (1997) found evidence for increased imports from Canada as a consequence of reduced National Forest harvest but inconclusive evidence for substitution of nonwood products or increased harvest on private lands.

Figure 6. Past and projected carbon sequestration in U.S. National Forests (from Birdsey and Heath 1995)



Short-Rotation Biomass Plantations

Short-rotation woody crops could be established specifically for biomass production on marginal cropland and pasture. Current average dry biomass yields for short-rotation crops (rotations less than 10 years) are approximately 12 t/ha/yr, with higher rates attainable (Wright and Hughes 1993). Very high rates of C sequestration are possible over longer periods in forests that are managed for biomass production. For example, the average C storage in biomass (including cut and dead trees) for 40-year old hardwoods in the Lake States under different management intensities was 331 Mg/ha (Strong 1995). This is equivalent to an average annual C accumulation of 8.3 t/ha/yr over the entire 40-year period.

Conversion of productive forestland to short rotation biomass crops may result in a decrease in ecosystem C storage that would have to be offset over several rotations by counting the substitution of wood biomass for fossil fuel energy. Cropper and Ewel (1987) compared C accumulation under existing forestry practices for slash pine (*Pinus elliottii*) and found that annual C storage decreased by more than half in some cases, due to reduced tree biomass and soil C.

The U.S. Congress, Office of Technology Assessment (1991) estimated that a program to plant about 1.25 million hectares of biomass plantations per year for 20 years would eventually produce 30 TgC/yr of harvestable biomass. The study estimated that about half of the harvested C would offset fossil fuel C.

Improved Utilization of Harvested Biomass

Heath and others (1996) estimated that of the 10,700 TgC harvested in the U.S. since 1900, 35 percent remained in products and landfills, 35 percent was burned for energy, and 30 percent emitted to the atmosphere without producing energy for consumption. Improved utilization of removed biomass could reduce losses of C to the atmosphere. For example, if the percentage of C in wood products were increased by 50 percent the annual C storage in products would increase by about 10 TgC/yr, while the other disposition categories (landfills, wood burned for energy, and emissions) would each be reduced by about 3.5 TgC/yr (Heath and others 1996). Also, retention in landfills could be increased as documented by Micales and Skog (1997).

Increased recycling of wood products may have two effects: keeping the C sequestered in usable products longer, and reducing the timber harvest. The U.S. EPA sponsored an analysis of recycling that concluded that each ton of recycled paper increased forest C sequestration by 0.73 tons (U.S. Environmental Protection Agency 1997). This estimate was derived from a cluster of U.S. Forest Service models including FORCARB and associated economic models of the pulp and paper industry. Another study estimated that rapidly increasing paper recycling to 45 percent of total fiber used would sequester an average of 10 TgC/yr (Heath and Birdsey 1993).

Plant Trees in Urban and Suburban Areas

Urban and suburban trees store C and can reduce energy use in buildings if the correct species are properly placed. Rowntree and Nowak (1991) estimated that urban areas in the U.S. have an average tree cover of 28 percent, and store an average of 27 t/ha. McPherson and Rowntree (1993) estimated that a single 7.6 meters tall tree could reduce annual heating and cooling costs of a typical residence by 8 to 12 percent, which both saves money and avoids the use of energy generated with fossil fuels.

Nowak (1993) concluded that planting an additional 100 million urban trees and maintaining them for 50 years would cumulatively store approximately 75 TgC in biomass and offset 275 TgC due to energy conservation. This is an annual average of 7 TgC/yr over the 50-yr period. The rate of sequestration would be very low for the first 2 decades, and higher toward the end of the period as the trees reach maturity (more than 10 TgC/yr). Assuming a cost of planting and initial tree maintenance of $5-25/tree, such a program would cost from $50 to $250 per ton of C after several decades (McPherson 1994).

Summary and Conclusions

If the U.S. is to meet the emission target, forestry could play an important, if not critical role, in this reduction. Globally, the most important activity that affects carbon fluxes is deforestation. However, in the U.S. the amount of forest land has remained fairly constant during the last several decades at approximately 298 million hectares or 33 percent of the total land area. Given the low rate of change in the area of forest land of the U.S., the major anthropogenic influences on the current net carbon flux are forest management and protection, forest product processing, urban tree planting, and research and transfer of environmentally sound policies and practices. Natural disturbances such as fire, insects, and diseases are locally important factors that affect forests and C storage.

The Kyoto Protocol establishes an accounting system that includes only part of the carbon attributable to forestry and land use change. The forestry baseline as described under article 3.3 would account only for forest lands that have been or will be affected by reforestation, afforestation, and deforestation since 1990. The exact definitions of these activities are not given in the Protocol. Additional activities such as forest management would not likely be counted unless accepted as additional activities under article 3.4 of the Protocol.

The net sequestration of C in U.S. forest ecosystems and wood products (including disposal in landfills) from all activities during the 1980's was about 300 TgC/yr, and is projected to be at least 200 TgC/yr for the next few decades. The causes of continued net sequestration in forests are varied. Forest management practices that may increase carbon storage include regeneration of harvested natural pine and oak-pine in the South to fast-growing plantations, increasing use of genetically improved planting stock, and maintenance of optimal stocking density for growth. Some areas of maturing forest in the North and some areas in the West are unlikely to be harvested, allowing stored carbon to reach higher levels than recent decades as long as natural disturbance rates are low. Increased use of partial harvesting methods that minimize impacts on stored soil carbon will increase retention of carbon on forest sites. Improved efficiency in converting roundwood to products, and increasing product's useful lifetime, will also contribute to net forest carbon sequestration in the U.S.

Regardless of how the Kyoto Protocol or any other international agreement to limit greenhouse gases may be implemented, forestry in the U.S. offsets a significant percentage of CO_2 emissions, and will continue to do so for a very long time. The value of forests for C sequestration should be widely recognized, and efforts to manage and protect this and other values of healthy forests continued.

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