Carbon Sequestration, Biological Diversity, and Sustainable Development: Integrated Forest Management[1]

MICHAEL A. CAIRNS*
United States Environmental Protection Agency
Environmental Research Laboratory
200 SW 35th Street
Corvallis, Oregon 97333, USA

RICHARD A. MEGANCK
United Nations Environment Programme for the Wider Caribbean
14-20 Port Royal Street
Kingston, Jamaica

ABSTRACT / Tropical deforestation provides a significant contribution to anthropogenic increases in atmospheric CO_2 concentration that may lead to global warming. Forestation and other forest management options to sequester CO_2 in the tropical latitudes may fail unless they address local economic, social, environmental, and political needs of people in the developing world. Forest management is discussed in terms of three objectives: carbon sequestration, sustainable development, and biodiversity conservation. An integrated forest management strategy of land-use planning is proposed to achieve these objectives and is centered around: preservation of primary forest, intensified use of nontimber resources, agroforestry, and selective use of plantation forestry.

Several international conferences and workshops in the past two years have proposed adoption of a global forestry agreement (Maini 1991). Progress is simultaneously being made toward international agreements on greenhouse gas emissions and protection of biological diversity, each of which have forests as mutual components (IPCC 1990). However, focus on a single objective may lead to a narrowing of public policy outcomes (Browder 1992). Thus, those concerned with greenhouse gas emissions propose managing the terrestrial biosphere to sequester carbon, typically focusing on lands suitable for forestation projects (Marland 1988, Winjum and others 1991); this single goal is unlikely to enlist the support of many local populations. Some concerned with loss of biodiversity have proposed establishment of nature reserves, while overlooking the socioeconomic needs of indigenous peoples for goods and services provided by the forests.

Global forestry, climate change, and biodiversity agreements are less likely to be successful if they ignore social, ecological, political, and economic objectives. The international development community directs large amounts of resources to developing nations to finance development projects. For example, the World Bank annually lends $17 billion to developing nations in tropical latitudes (Goodland 1990). Such projects historically included some environmental assessment in their planning, but usually on an ad hoc basis, and not as an integral component (NRC 1982); rarely did such projects specifically consider effects on global climate or biodiversity. The World Bank's recent adoption of a "wildlands" policy (Ledec and Goodland 1988) and publication of a new forestry sector policy paper (The World Bank 1991) indicate that this is changing.

Here we describe an integrated forest management approach that recognizes the interdependence and collateral benefits of addressing the three global issues. Integrating reduction of greenhouse gas emissions, conservation of biodiversity, and sustainable economic development strategies is described. Ecological, social, political, and economic concerns are interconnected and can all be considered in project planning. We seek to show how the elements of integrated forest management may complement each

KEY WORDS: Integrated forest management; Carbon; Greenhouse gas; Biodiversity; Sustainable development; Tropical forestry; Socioeconomic

[1]The information in this document has been wholly funded by the US Environmental Protection Agency. It has been subjected to the agency's peer and administrative review and approved for publication of an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

*Author to whom correspondence should be addressed.

other and contribute to solutions to the three environmental issues.

Integrated forest management focuses on slowing deforestation because (1) primary forests contain more carbon per unit area than any other land-use type; (2) conversion, destruction, and simplification of natural forests (e.g., clear-cutting and replacement with monoculture plantations) are primary causes of large biodiversity losses; and (3) natural areas can provide a sustainable livelihood for people living in or near the forests.

In the interest of clarity, sustainable development as used in this article was defined by the Brundtland Commission as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). One prerequisite for sustainable development is sustainable use of the available stock of natural resources. Expressed in a slightly different way, sustainable development means "improving the quality of human life while living within the carrying capacity of supporting ecosystems" (IUCN/UNEP/WWF 1991).

Carbon Storage

Forests sequester more than 92% of the world's terrestrial carbon and store between 20 and 100 times more carbon per hectare than agricultural lands (Andrasko 1990, Houghton 1990a). Brown (1988) reports that tropical moist forests average between 155 and 187 t C/ha, and tropical dry forests between 27 and 63 t C/ha, depending on location. Similar carbon biomass figures for Brazilian Amazonia range from 140 to 200 t C/ha (Salati and others 1989). Undisturbed moist tropical forests show net growth, and net carbon sequestration, for 100 years after establishment (Kyrklund 1990).

Although young plantation forests sequester carbon at a higher rate than mature forests, primary forests conserve much more carbon per hectare, preventing its release to the atmosphere. Plantations established on degraded secondary forest or nonforested land can increase the size of the terrestrial carbon pool, while preserving old-growth forest can help conserve the terrestrial carbon pool. Even though organic carbon stored in mature forests is released through fire and oxidation, the gaps thus created provide opportunities for new tree establishment if natural regeneration is allowed to proceed. When plantations reach a mature stage, the net carbon sequestration stops. Therefore, the value of plantation forestry in carbon sequestration rests in its temporary utility while alternatives to fossil fuel use can be developed.

Table 1. Mean carbon storage of various ecosystem types[a]

Ecosystem	Carbon storage (t C/ha)
Tropical forest	220
Temperate forest	150
Boreal forest	90
Grassland/savanna	15
Agriculture	5

[a]Source: Waring and Schlesinger (1985).

Primary forests sequester large amounts of carbon in aboveground biomass, roots, litter, and soils. Most of this carbon is lost when such forests are removed and replaced by plantations or other land uses (Harmon and others 1990). As an example, the conversion of 5×10^6 ha of western Oregon and Washington old-growth forests to plantations in the last century released between 1.5 and 1.8 Gt of carbon to the atmosphere (Harmon and others 1990). The same authors reported that a 450-year-old *Pseudotsuga–Tsuga* stand stores approximately 350 t/ha of aboveground carbon, compared to 158 t C/ha in a 60-year-old *Pseudotsuga* plantation. Carbon storage in plantations does not approach that in old-growth for at least 200 years. Western Oregon and Washington forests, representing only 0.017% of the planet's land area, have contributed 2% of the total carbon released in the last 100 years by land-use conversion (Harmon and others 1990, Woodwell and others 1978). Large old trees conserve substantial quantities of carbon as biomass for an indefinite period of time, even if they do not produce large amounts of timber (Norse 1990).

It is useful to examine the relative mean biomass of various ecosystems to put the carbon storage comparison in perspective (Table 1). Tropical forests harbor more carbon than other ecosystems, 44 times as much as agricultural lands (Waring and Schlesinger 1985).

These data illustrate the tremendous impact that tropical forests have on the global carbon cycle. Conversion of forests to less complex ecosystems (e.g., pastures) results in a large carbon flux to the atmosphere. Preservation of primary forests for carbon sequestration/conservation may be more efficient and have fewer negative long-term ecological, social, and political results than plantations established for this purpose (Flavin 1989, Postel and Heise 1988).

Carbon loss associated with deforestation occurs more rapidly than reforestation can sequester carbon. In addition, the current land area under forest cover is greater than that available for reforestation. It may be less effective to focus on plantation forests, as advocated by some scientists and policy makers, except as an offset to cutting more primary forest (Kyrklund 1990, Winjum and others 1991), if the newly planted trees will soon be cut. It may be less expensive to slow deforestation than to reforest large areas for many socioeconomic and ecological reasons (Flavin 1989, Postel and Heise 1988). Therefore, slowing deforestation might have a larger impact on the global carbon cycle than reforestation (Goodland and others 1990; Houghton 1990a,b). Halting net deforestation could reduce annual global carbon emissions by roughly 2.5 Gt (Houghton 1989).

Efforts to slow deforestation have focused initially on key tropical countries: Brazil, Indonesia, Myanmar, Columbia, Cote d'Ivoire, Thailand, Nigeria, Laos, Philippines, Peru, and Ecuador (Houghton 1989). These 11 nations produced 72% (1.185 Gt) of the total deforestation carbon release of 1.659 Gt in 1980 (Houghton and others 1987). Forest management that employs conservation of primary forests concurrently supports the goal of maintaining biological diversity.

Biological Diversity

More than half of all species of plants and animals live in tropical moist forests (Myers 1979, Raven 1976), somewhere between three and ten million species (Raven 1988, Wilson 1988, WRI/IIED 1986). Less than 500,000 of those species have been described or even named.

We may see a reduction of 10% of the Earth's species by the turn of the century, given current extinction rates (Raven 1988). Tropical moist forest species alone are being reduced by 17,500/yr, according to one approximation (Wilson 1988). This compares to a background rate of approximately one species per year, before large-scale human influence (Raup 1978, 1986). A principal reason for this loss of species is the annual destruction of between 76,000 and 92,000 km^2 of primary forest (Myers 1988, Wilson 1988). To put these numbers in perspective, primary tropical forests now cover 9 million km^2 out of a precolonization area of 15 million km^2 (Raven 1988).

Loss of biodiversity accompanying conversion of forests has many social impacts. Utilitarian values of biodiversity include goods and services provided by the biosphere. Tangible goods include food, fiber, natural pesticides, medicines, fuels, and industrial chemicals. Ecological services include water and air purification, natual pollination, soil formation and maintenance, pest protection for crops and livestock, groundwater recharge, watershed protection, buffering of floods and droughts, and sequestration of carbon (Meganck and Saunier 1983). Local societies may suffer when forests are disrupted and the provision of goods and services is interrupted.

Intact forests conserve large amounts of carbon, while providing the ecological goods and services which form the basis for sustainable economic development. One might assume that ecological services can as easily be provided by less diverse ecosystems. However, organisms are highly adapted to specific environments, and substitutions are likely to be inadequate (Ehrlich and Wilson 1991).

Options that allow for both the well-being of individuals and the protection of the forests may be more successful in slowing deforestation, loss of biodiversity, and greenhouse gas emissions (Nations 1988). Research is needed to evaluate the practical benefits derived by local people who preserve primary forest ecosystems. Input of local societies is vital to sustainably managing the biosphere (McNeely and others 1990).

Demonstrating the practical economic values of biodiversity has been difficult. Tropical forest ecosystems are converted to provide immediate economic gain: crops, fuelwood, cattle, and timber. Consumption rates may be impacting the sustainability of the natural resource base and rendering resources nonrenewable (Whitmore 1984). It is important, therefore, to determine and characterize the role of primary forests and their biotic capital in development and economic growth. Economic arguments and inducements may be the most effective because people generally define self-interest in economic terms.

Treatment of biotic resources as traditional market commodities, particularly in market economies, has been identified as a major economic cause of loss of biodiversity (Clark 1973, McNeely 1988, Norgaard 1984, Randall 1979). Those who receive the benefits of exploitation of the biosphere often do not pay the full costs of such exploitation. Rather, these external costs are paid by the resource-providing countries. Other important economic issues contributing to loss of biodiversity are: (1) whereas the benefits of exploiting biotic resources are easily quantified, the benefits of preservation are not fully represented in traditional cost/benefit analyses because those benefits are widespread, intangible, and not reflected in market prices (Oldfield 1984); (2) biological resources are usually publicly owned (weak ownership) with open access and often treated as free commodities with a high consumer demand on them; (3) discount rates in development planning are often set too high compared with biological growth rates, so that it is calculated to be economically efficient at times to deplete biotic resources to extinction (Clark 1976); and (4) measures of national income, such as gross national product (GNP), do not recognize the drawing down of natural resource stocks but actually consider biodiversity depletion as net income, so that GNP often rises while natural assets are rapidly declining (Warford 1987).

Despite the difficulties in placing a dollar value on biodiversity, it is informative to discuss the biosphere in monetary terms and some have attempted this (Barrett 1988, Johansson 1987, Peters and others 1989, Prance and others 1987, Westman 1977). Peters and others (1989) concluded that certain managed natural tropical forests are worth considerably more intact than the market benefits realized from large-scale timber harvesting, whether the plot is replanted with trees or dedicated to another agricultural use. Sustained production of a range of marketable products may be directly tied to the maintenance of natural forests and their biotic goods and services, many of which are lost when forest is permanently converted (Meganck and Goebel 1989). Barbier and others (1991) conclude that undervaluing these services can "often reinforce and even exacerbate these (large-scale land clearing) tendencies by employing misguided policies and sanctioning inappropriate resource rights to forests." Although all the benefits of conserving biodiversity cannot be quantified in strictly monetary terms (Ehrenfeld 1988), innovative economic analysis of the goods and services provided by the biosphere can help assign at least a minimum value to biodiversity.

At times, nations encourage, through various economic incentives, destructive logging practices to meet international market demands, clearing and biomass burning for cattle ranching, and settlement programs for agriculture (Cartwright 1985).

Integrated economic development may require that industrialized nations join developing nations as partners. Developed countries reap the benefits of use of the planet's biotic resources much more so than the developing countries, as evidenced by the comparative per capita energy and resource consumption. Foreign debt, poverty, and rapidly growing urban populations aggravate the unsustainable exploitation of the biotic resource base. Developed countries and development banks have recently begun to increase financial assistance to LDCs to address the causes of loss of biodiversity (Cartwright 1985, Muthoo 1990, Raven 1990).

An innovative means of preserving biodiversity is the use of debt-for-nature swaps (Dogse and von Droste 1990). First proposed in the early 1980s (Lovejoy 1984), these complex financial transactions typically involve at least three principals: (1) the debtor country, usually a tropical LDC; (2) the debt holder or creditor bank; and (3) a conservation investor, typically a nongovernmental environmental organization such as World Wildlife Fund, Conservation International (CI), or The Nature Conservancy.

The basic mechanism of such exchanges is that the debt holder negotiates with the debtor country through a conservation investor, in a secondary debt market, to forgive the debt in exchange for the debtor government's pledge to invest in various conservation or development projects in the debtor country. Although there are potential disadvantages (Dogse and von Droste 1990), the debtor nation has some of its debt burden forgiven, the debt holder clears its books of some of its probable losses, and various conservation projects and local environmental organizations are funded. This practice was initiated in 1987 with a swap involving Bolivia, CI, and Citicorp Investment Bank. The agreement provided full legal protection for the Beni Biosphere Reserve (CI 1989). During the next three years, 19 exchange programs involving 11 countries and more than US $300 million face value of debt were established (Dogse and Von Droste 1990). Most important for biodiversity, more than US $58 million in conservation funds were generated.

Sustainable Development

In 1989, more than 1.2 billion people, largely in the rural tropics, lived in absolute poverty, defined as the lack of adequate resources to meet essential biological needs for food, clothing, and shelter (Brown 1990). Such people, in a quest for subsistence needs, often turn to the resources of tropical forests. The result is often forest degradation, deforestation, depletion of biodiversity, and release of CO_2 to the atmosphere (OTA 1984). As the forests' biotic resources are depleted, poverty is further accelerated and the cycle continues.

Because poverty in the tropics is both a cause and a result of habitat conversion, in order to slow deforestation, development should proceed in ways that discourage the locally irreversible deforestation now occurring in some tropical countries (Uhl 1983). In the past, most funding by the development banks was for large infrastructure projects, such as hydroelectric dams, power plants, and coal mines, sometimes having large negative social, economic, and environmental impacts. Recently, however, bilateral and multilateral development agencies have begun merging ecological considerations into socioeconomic development policy decisions (Ledec and Goodland 1988, USAID 1987) rather than relying solely on neoclassical economic formulae to justify such projects.

Sustainable use of biotic resources, including forested lands, may allow development to achieve long-term provision of essential human needs. To ensure that the requirements of the most needy are met, the local populace should be an integral partner in the planning and implementation of development projects. This requires understanding of the social, cultural, and political nature of those most directly affected. Such understanding may be gleaned from the mutual interests of economic development experts, social scientists, and tropical ecologists (Goodland 1990, WCED 1987).

Quality of life, as measured by per capita income, is lower in the developing world than it was 30 years ago, even though GNP has increased at an average rate of 3% per year (Brown 1990, Goodland and Webb 1990, Summers and Heston 1988). This is due to both population growth and the practice of living off the basic economic capital of the renewable biotic resources, rather than the interest from that capital (MacNeill 1989). Strategies that protect biodiversity and enable tropical people to sustainably meet essential needs are also likely be successful in conserving carbon to help stem global warming.

Integrated Forest Management

Loss of biodiversity and accumulation of greenhouse gases through deforestation often result from efforts to satisfy local survival needs. However, local people will probably not be interested in adopting practical strategies to reduce greenhouse gas buildup or loss of biodiversity unless their immediate needs for improved quality of life are addressed (Nations 1988). Ecologically and economically sustainable forest management practices can provide goods and services for local people in the present while preserving options for future generations. The type of forest management described here consists of measures that will displace demand on primary forests to slow deforestation, protect biodiversity, and partially offset global warming.

A proposed four-point program of integrated forest management is described: (1) land-use planning emphasizing primary forest preservation and management, (2) intensified use of nontimber resources, (3) agroforestry applications, and (4) plantation forestry in appropriate situations.

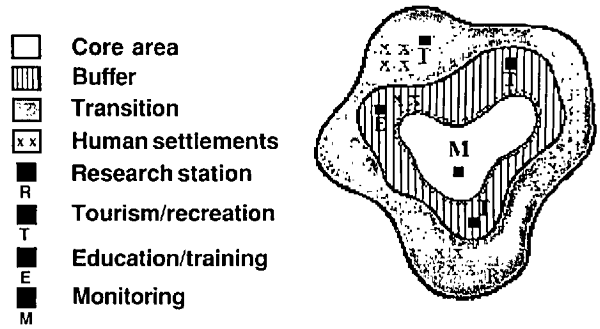

Figure 1. An idealized biosphere reserve model. (*Source:* Dixon and others 1991.)

Land-Use Planning

Land-use planning, tailored to local conditions and emphasizing primary forest preservation and management within an economic development context is gaining favor in many conservation and financial communities (Ledec and Goodland 1988, MacKinnon and others 1986, McNeeley and others 1990). An example is the biosphere reserve concept (Batisse 1982, 1990, Miller 1978), in which conservation and protection of natural ecosystems share the focus with sustainable development. Several land-use categories are used, representing wide ranges of development, intensity of use, management objectives, and sustainability (Meganck and Saunier 1983). For example, development may range from "permanent" alteration for intensive agriculture to strict nature preservation. Management objectives may include: maintaining ecosystems in a natural state to protect water supplies, providing timber on a sustained yield basis, and providing tourism opportunities. Ecological sustainability in the various categories increases from agriculture to plantation forestry to intact forests.

Clearly, prioritizing management objectives will involve weighing the most pressing needs at local, regional, national, and global scales. We suggest that provision of essential local economic activities, preservation of biological diversity, and conservation of terrestrial carbon with all be optimized when forest ecosystems are maintained in a near-primary state. Economic development priority decisions can be made in this context.

In the biosphere reserve model (Figure 1), wilderness areas, as well as primary forests not currently protected as legal reserves, are identified, established as core areas, and afforded protection. One or more land uses can be employed in areas surrounding the preserve to buffer the core areas and to provide for sustainable utilization of resources. Selective logging may be appropriate in some places, as may seasonal grazing, hunting, tourism, or agroforestry. Outside the core area in the surrounding buffer zone, more intensive agricultural practices can be conducted in transition areas. The planned use areas provide a buffer from pressures on the core nature reserve. In addition, natural regeneration and active restoration management of the forests may in time permit expansion of the protected core. Protected managment areas can preserve further options while sustaining the present generation through a planned mix of various categories of reserves, amidst productive farms and forests.

If economic development is defined as the use, enhancement, and protection of biotic goods and services and as actions that improve quality of life by lowering risk from natural hazards, then preservation and conservation can be considered significant development activities (Meganck and Saunier 1983). For example, preserving an upland watershed to provide erosion control and downstream fisheries is as much a development activity as are industrial forestry and dam building projects.

Nontimber Resources

A second point of the integrated forest management plan is the intensified use of nontimber biotic resources, including both forested and nonforested lands. In 1980, only 750 million of the 1.8 billion ha of potentially arable land in the developing world was cultivated. The FAO (1980) estimates that 85% of the projected food production to the turn of the century could come from a combination of expanding land under cultivation and increasing yields. To help address needs for food, such conversion of suitable nonforested lands and intensification of agriculture would help to relieve pressure on primary forests (Spears and Ayensu 1985).

Consideration of agriculture is essential because forest-sector land-use conversions are frequently determined by processes in the agricultural sector (Grainger 1990). Crop yield improvements are needed on lands best suited for sustainable agriculture to displace intrusion into primary forests.

Additionally, tropical forests should be recognized as having substantial economic market value beyond their timber resources. This will require development and general acceptance of a valuation systems for biotic resources traditionally considered to be outside the market economy. The market value of edible fruits, latex rubber, and other products from a small plot of rain forest was far greater than that of the timber (Peters and others 1989). The markets for these nontimber products should be expanded to provide livelihoods and prevent deforestation.

Another nontimber use of tropical forests is exemplified by extractive reserves in Brazil (Fearnside 1989). Maintaining sizable areas of Amazonia for extraction of products like Brazil nuts and natural rubber has become locally effective in protecting forests for biodiversity and carbon conservation because it provides sustainable economic activity for indigenous people.

Meat from wildlife species is food and a source of income for much of the developing world (Ntiamoa-Baidu 1987). Human population pressure and habitat destruction are seriously depleting wildlife resources. Needs are great for applied research on conservation of habitat, management for utilization, pest control, and tourism. Saving these valuable food resources will require saving the forests they inhabit.

Another use of tropical forest animals is in domestication projects. Both butterflies and crocodiles are farmed in Papua New Guinea; iguanas and pacas are raised for their meat in Panama (Vietmeyer 1988). These are a few of the many species that could provide incomes for indigenous people by exploiting the nontimber values of the forests.

Agroforestry

Traditional, sustainable, swidden/fallow agriculture has been practiced in Amazonia for several thousand years (Dufour 1990, Winterbottom and Hazlewood 1987). Today this region contains less than 500,000 indigenous people, but 6.8 million Amerindians once lived there by cultivating small, polycultural, multistory plots, including trees (Denevan 1976). Even more recent residents of Amazonia, the caboclos, or rural peasants who practice a market economy, employ swidden/fallow farming in what is thought to be a sustainable and ecologically beneficial way (Fearnside 1989).

Nations and Nigh (1980) documented the vanishing Lacandon Maya culture of Chiapas, Mexico, who still practice a form of sustainable tropical forest agriculture (agroforestry). Such indigenous people produce food on deforested plots, then regenerate the area with forest species in order to produce more food in the future.

The most recent colonists, arriving with little knowledge of the rain forest, sometimes treat the forest ecosystem as an adversary rather than a valuable resource (Drennon 1990). Such destructive practices are characteristic of cultures colonizing uninhabited territory and those in a stage of rapid cultural transition (Soule 1991).

Agroforestry relies on the complex interactions between trees and other elements of the system, provides habitat for biological diversity, and produces goods and services (Winterbottom and Hazlewood 1987). Although the number of agroforestry system types is nearly as large as the number of localities where they are practiced, most types employ one of three combinations. Agrosilviculture combines trees and annual crops, silvopastoralism combine trees and grazing animals on wooded pasture or rangeland, and agrosilvopastoralism combines trees, crops, and livestock (Mergen 1986). The major benefits of agroforestry frequently include low technological input, sustainable use of secondary forests, maximization of productivity and income, and control of deforestation (Winterbottom and Hazlewood 1987). In a typical system, trees may provide shade and increased soil nutrients for crops such as coffee, fuelwood for home use, aerial fodder for livestock, and shelterbelts that increase soil moisture while moderating air temperatures. Although no single agroforestry application will provide all possible benefits, successful systems are documented throughout the temperate and tropical biomes, and the potential for application of agroforestry systems is significantly untapped (Nair 1985).

Plantation Forestry

Plantation forestry may be appropriate where there is an urgent need for watershed rehabilitation, an acute fuelwood shortage, or where it can substitute for unsustainable industrial wood harvest (Goodland and others 1990). Tree plantations located in close proximity to primary forests may be valuable in displacing destructive pressures on such forests.

Environmental degradation and human misery resulting from unsustainable forest harvesting is exemplified by the global fuelwood shortage. It is projected that by the year 2000, 2.4 billion people, half the developing world population, will either not be able to meet their minimum fuelwood needs or will meet their needs only be depleting their wood resources (FAO 1983). People often spend most of their time gathering firewood rather than in more productive pursuits and settle for easily prepared, less nutritious food. In many cases, animal manure and plant residues are burned for fuel rather than incorporated into soils, lowering future crop yields. In many urban tropical areas, people spend a substantial portion of their income for fuelwood, contributing to poverty. Plantation forestry is appropriate to help solve the fuelwood crisis.

Another appropriate use of tropical plantations is in carbon sink forests, established to offset present or future emissions of CO_2 In 1988, the first such project was jointly initiated by Applied Energy Systems (AES) and the World Resources Institute; CARE, USAID, the Peace Corps, and the government of Guatemala eventually became partners in funding the venture at US $16.3 million (Trexler and others 1989). The potential success of this project lies in its promotion of multiple objectives: 52 million trees to be planted on 72,000 ha in Guatemala are expected to sequester 18 million tons of CO_2 to offset the 15.5 million tons to be released in the next 40 years by a Connecticut power plant; 40,000 rural families will potentially gain employment in the propagation, planting, and maintenance of seedlings; plantations may provide further economic development opportunities by establishing fuelwood lots, agroforestry applications, and soil stabilization services; and plantations can displace demand on primary forests, which can then continue to sustainably provide needed goods and ecological services. The last objective is projected to account for approximately 80% of the total long-term carbon sequestration potential (Trexler and others 1989), while enhancing the preservation of biodiversity and aiding sustainable development. Future carbon sink forest endeavors will benefit from the recognition that socioeconomic factors and institution building are perhaps more important than scientific calculations in predicing the long-term success of such projects.

Conclusions

No-regrets policies, actions that "make sense" for various social, economic, or ecological reasons and that reduce greenhouse gas buildup as an ancillary benefit may be accepted by people of developed and developing nations. Integrated forest management to maintain the natural resource base essential for economic development may help to meet the needs of the expanding human population in the tropics. In the process, carbon, biodiversity, and other resources can be conserved to meet societal goals.

Research is needed to determine the amount of land that is ecologically and socioeconomically available to apply integrated forest management. We subsequently envision adaptive management, a series of incremental changes in the mixture of conservation practices, nontimber uses, agroforestry practices, and plantation forestry to arrive eventually at the optimal mixture within an integrated forest management framework.

In a sense, we do not understand enough about the biosphere to manage it in detail; it best manages itself (Woodwell 1985). Conversely, we do manage natural resources on a local scale; we either destroy or modify them or we preserve them for sustainable use. The paramount need is to manage biotic systems with practices that allow for ecological and economic sustainability.

An integrated forest management strategy would include land-use planning centered on preservation of primary forests, intensified use of nontimber resources, agroforestry applications, and selective plantation forestry.

Acknowledgments

The authors thank D. Blockstein, M. Brklacich, P. Carver, R. Dixon, M. Freed, A. Hairston, R. Huber, R. McKelvey, G. Mendoza, G. Oberst, D. Peterson, and P. Schroeder, for critical reviews and constructive suggestions for modification of earlier drafts of this article.

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