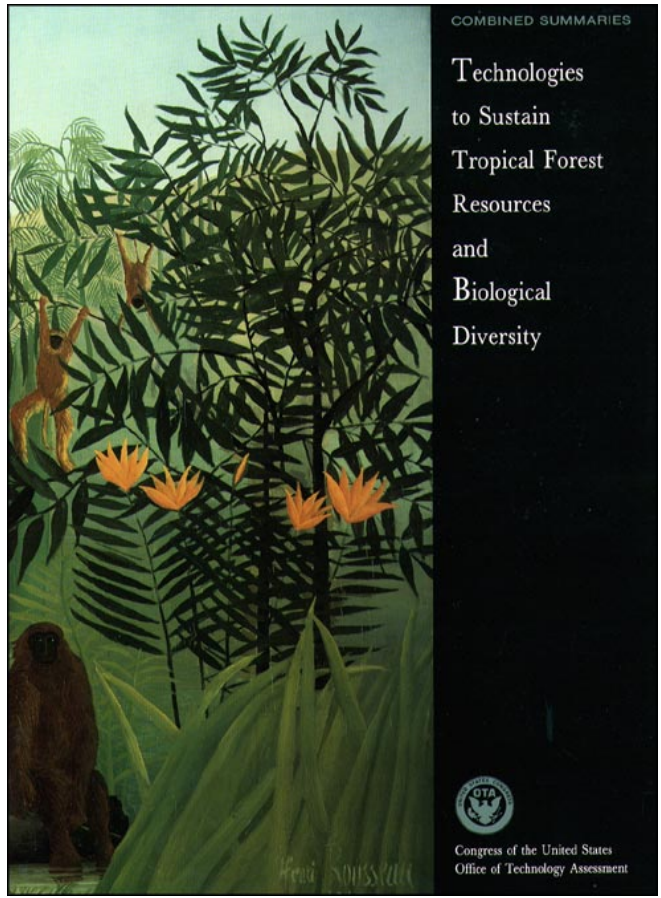
Combined Summaries: Technologies To Sustain Tropical Forest Resources and Biological Diversity

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Foreword

Loss of tropical forests and reduction in the Earth's biological diversity have grown from development assistance concerns to themes of global debate during the last decade. At the same time that the value of biological resources to local communities and individual nations has become more fully appreciated, the connections between these resources and global environmental stability and economic development potential have been uncovered.

Loss of tropical forests still is associated with poverty in tropical developing nations, but it now is juxtaposed with potential disruption of global weather patterns. Reduction in biological diversity still impedes communities from diversifying their development options, but it also may preclude development of some new products and processes that could support global advances in agriculture, medicine, and industry. And, because of the biological richness of tropical forests and our incomplete knowledge of their resources, tropical forest conservation and protection of biological diversity have become inextricably linked.

In the years since the Office of Technology Assessment published *Technologies to Sustain Tropical Forest Resources (1984)* and *Technologies to Maintain Biological Diversity (1987),* new issues have arisen, new approaches have been devised, and new policies have been adopted. Yet the technologies underlying efforts to manage the resources sustainably have changed little. Thus, in continuing service to Congress, OTA is reprinting the summaries of the two earlier assessments and is providing an introduction to the changes that have occurred since their publication.



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Introduction to Combined Summaries

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Introduction to Combined Summaries

Policy makers have become increasingly concerned with conservation of natural resources over the past decade. When OTA published its assessment *Technologies To Sustain Tropical Forest Resources [58]* for the U.S. Congress, policymakers in America and abroad were just beginning to appreciate the implications of rapid destruction of the tropical forest biome. Tropical forests provide environmental services and fundamental life support to many of the world's people, and house an estimated two-thirds of the world's plant and animal species. Subsequently, OTA published *Technologies To Maintain Biological Diversity [57]* for the U.S. Congress, addressing specific means to protect genetic, species, and ecosystem diversity. Because of the biological richness of tropical forests, the issues of tropical forest loss and species loss are inseparable.

Since the early 1980s, new estimates of the loss of tropical forests and of biological diversity-biodiversity-have generated increasing alarm. Data on tropical deforestation remain imprecise, but the most recent figures indicate the forest loss rate is at least as high as estimated in the mid- 1980s. By one recent estimate, tropical forest now is disappearing 40 percent faster than a decade ago [3 1]. Data on loss of individual species is yet more difficult to obtain, but populations and their genetic heritage certainly are lost as habitats are degraded. The loss of tropical forests and declining biodiversity have serious implications for human populations. As biodiversity declines, the quest for new pharmaceuticals, renewable industrial feedstocks, and other such natural resource products, and the search for genetic materials to supply agricultural and medicinal biotechnology efforts are less likely to yield results. Further, the role of tropical forests in stabilizing global climate has become better known. For both reasons, the search for policies that will promote conservation of forests and biodviersity and for technologies to implement those policies has become more urgent.

Congressional concern with international environmental protection has increased markedly over the last decade; a key issue in the 1980s was how to help foreign assistance agencies respond to problems of tropical deforestation and loss of species. U.S. foreign assistance programs began incorporating environmental concerns in the late 1970s when a series of amendments to the Foreign Assistance Act defined the Agency for International Development's (AID) mandate in the area of environment and natural resource management. These amendments specifically emphasized promoting efforts to halt tropical deforestation and maintain biodiversity, and led to further congressional actions in the 1980s (box A).

With congressional guidance, AID rapidly increased its investment in tropical forestry and international biodiversity programs. Policymakers for multilateral institutions, other countries' bilateral assistance agencies, some developing country governments, and many nongovernmental organizations (NGO) also moved in this direction. Consequently, international efforts to conserve forests and biodiversity increased rapidly. Significant progress has occurred with institutional commitments and policy developments; technical solutions, however, have been slow to develop.

A few apparently successful conservation efforts suggest that deforestation and biodiversity loss are not wholly intractable problems. However, existing problems largely result from complex institutional, political, social, and technical causes. The international assistance agencies and concerned developing country governments have not yet demonstrated general solutions, nor have they learned how to reverse deforestation and extinction trends. Thus, continued leadership by Congress is likely to be necessary to sustain the momentum already achieved.

OTA's tropical forest and biodiversity assessments indicated that policy and institutional constraints on conservation of forests were more severe than technical constraints. Today, as organizational structures, policies, and funding for ecologically sustainable development are becoming functional, the importance of technical constraints seems to be increasing. To support the amplified congressional interest, and because of the close relationship between maintenance of tropical forests and biodiversity, OTA is reissuing the two assessment summaries in a combined form. This publication incorporates updated information related to these

Box A—Amendments to the Foreign Assistance Act Concerning Tropical Forests and Biological Diversity

1977: Amended section 102 to *102* environment and natural resources to areas the U.S. Agency for International Development (AID) should address.

1977: Added new section 118 on 'Environment and Natural Resources," authorizing AID to fortify "the capacity of less developed countries to protect and manage their environment and natural resources" and to "maintain and where possible restore the land,vegetation, water, wildlife, and other resources upon which depend economic growth and well-being, especially that of the poor."

1978: Amended section 118, requiring AID to carry out country studies in the developing world to identify natural resource problems and institutional mechanisms to solve them.

1978/79: Amended section 103 to emphasize forestry assistance, acknowledging that deforestation, with its attendant species loss, constitutes an impediment to meeting basic human needs in developing countries.

1981: Amended section 118, making AID's environmental review regulations part of the Foreign Assistance Act, and added a subsection (d), expressing that "Congress is particularly concerned about the continuing and accelerating alteration, destruction, and loss of tropical forests in developing countries. " Instructs the President to take these concerns into account in formulating policies and programs relating to bilateral and multilateral assistance and to private sector activities m the developing world.

1983: Added section 119, directing AID in consultation with other Federal agencies to develop a U.S. strategy on conserving biological diversity in developing countries.

1986: Redesignated section 118 as section 117, with the new section 118 addressing tropical forest issues. Amended section 119, which among other things earmarked money for biological diversity projects.

1988: Directed AID to monitor the economic and environmental soundness of multilateral development bank programs and projects.

1990: Directed AID to increase the number and expertise of staff in environmental and natural resources fields, and to focus efforts on developing countries projected to produce substantial amounts of greenhouse gases to the atmosphere.

SOURCE: Adapted *from* Us. Congress, Office of Technology Assessment, Technologies to Maintain Biological Diversity, OTA-F-331 (Springfield, VA: National Technical Information Service, March 1987).

global ongoing renewable resource problems, and introduces new issues and approaches that have arisen since publication of the original OTA reports.

NEW PUBLIC AND CONGRESSIONAL ISSUES

Congressional committees in the early and mid-1980s requested OTA assessments of technologies to sustain tropical forests and biological diversity largely for two reasons: interest in promoting sustainable economic development in tropical developing countries, and concern over the loss of product opportunities and species of interest to U.S. citizens. Since then, new, related public policy issues have wisen. Some of these underscore the need to conserve forests and biodiversity, whereas others constrain efforts to do so. Governments, development assistance agencies, and nongovernmental organizations are promoting a variety of policies to address these new issues as they grow in prominence.

Global Climate Change

Forests store a substantial part of the Earth's carbon. Deforestation and forest degradation worldwide, but especially in tropical regions, release carbon stored in the wood and forest soil as carbon dioxide (C@) gas, one of the gases implicated in global climate change. Net tropical forest loss accounted for about one quarter of all carbon released to the atmosphere over the past decade [5,56]. Halting deforestation would reduce this contribution to climate change and preserve an important carbon ''sink. ' Further, tropical reforestation and careful forest management may have

significant potential to help remove carbon gas from the atmosphere. The growing season in many parts of the tropics is year-round, whereas in temperate regions the growing season is much shorter. Reforestation, therefore, will trap $C0^2$ more quickly in the tropics than in temperate areas. Once forests reach maturity in either region, however, their growth slows considerably and additional storage of $C0^2$ decreases, necessitating some amount of harvest and replanting to continue carbon sequestration.

Biodiversity is greatly at risk from global warming. First, natural ecosystems, for example the Serengeti Plain in East Africa and the Florida Everglades, cannot move as climate zones shift rapidly. Some species will not be able to adapt to the changing characteristics of their surroundings and, thus, probably will be lost. Secondly, because of potential sea level changes, coastal zones and wetlands-biologically the most diverse ecosystems next to tropical forests-are the ecosystems most at risk from the effects of climate change [4].

Land-Based Sources of Coastal Pollution

Coastal zones, particularly wetlands, estuaries, and coral reefs, have high biodiversity and generally are of great economic importance. Pollution of these ecosystems from land-based sources-such as sediment eroded from cut-over forests and fertilizers and sediment transported from poorly managed famlands-sharply reduces the ability of estuaries and coral reefs to support diverse marine species [9]. At Bacuit Bay in the Philippines, economists and natural and social scientists measured revenues from logging, fisheries, and tourism in an area where sediment pollution from the logging operations had damaged the marine environment. The analysis showed that total income would double if logging ceased [12]. However, as is commonly the case, normal market forces did not result in pollution control. As the timber company did not incur the costs of lost fishery and tourism income, apolitical decision was necessary to stop the logging.

Natural coastal mangrove forests typically have very high biological productivity. The high organic production is exploited by many fish, and certain marine crustaceans spend part of their life cycles inhabiting the mangrove environment. The net energy outflow from mangrove habitats has beneficial effects on marine fisheries. The livelihoods of hundreds of thousands of people in coastal regions are at risk because mangrove forests are being degraded by pollution, overcutting, and human-caused hydrological changes [21].



Photo credit: Alison L Hess, Office of Technology Assessment

Coastal **mangrove forests capture sediment from freshwater runoff, protect inland vegetation from salt spray and tidal surges, provide high levels of nutrients for nearshore aquatic life, and provide habitat for a diversity of species. Thus, loss of these forests can compromise the livelihoods of entire coastal communities through diminished agricultural and fishery productivity, increased exposure to weather hazards, or reduced tourist income.**

Human Contact With New Diseases

AIDS[1], Ebola virus, and Marburg disease are a few of the highly infectious and commonly fatal ''emerging viruses" that have struck human communities in recent years. Many of these viruses are not new, but derive from new human exposure to disease-carrying animal populations. As human settlement extends into previously uninhabited tropical forests, exposure increases to new organisms, some of which may carry diseases that can spread to more general populations [70]. For example, monkeypox is a new human orthopoxvirus infection that occurs in remote villages sited in tropical rainforests of West and Central Africa [2]. Tegumentary leishma-

[1] Acquired immunodeficiency syndrome.

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niasis is a human parasitic disease prevalent in Colombia's Pacific coastal forested areas, where insect vectors and animal reservoirs seem impervious to control measures [64].

Moreover, ''changes wrought by war, migration, agriculture, deforestation and population growth have expedited the movement of viruses from isolated animal reservoirs to the larger, human community' [29]. Rainforest clearing for agriculture in western Africa provided prime breeding grounds for the malaria-carrying mosquito, which subsequently supplanted other species that could not adapt to the new environment. Empty coconut and cacao hulls provide breeding pools for disease-carrying mosquitoes and midges around the tropical world; other insect species preferentially breed in artificial containers that accompany human settlement. Disease-carrying rodents flourish in expanding grasslands and grain fields. Even the yearly outbreaks of common influenza are associated strongly with fish-waterfowl-swine aquiculture systems practiced in Southeast Asia. Yet viral emergence is rarely if ever taken into consideration in development activities. One proposal to contain the spread of infectious disease would be to establish a worldwide network of research and response centers for international disease surveillance and health programs [29]. A complementary approach would be to include "viral traffic planning in development plans" and to conduct regular "viral impact assessments" for development projects likely to involve changes in land use or ecological systems [30].

Multiplied and Magnified Disasters

Rural populations continue to grow rapidly throughout the developing nations, and continue to spread agriculture into marginally productive and physically hazardous regions. The consequent damage to tropical forests is most severe in infertile dry woodlands of rapidly growing countries such as Kenya [24]. Even in wetter, more fertile areas, however, population growth coupled with land-extensive farming practices leads to deforestation. In the Philippines, for example, so many landless poor have emigrated from the fertile lowlands that nearly one-third of the country's population now lives in the once-forested upland areas. There, relatively infertile soils necessitate practicing shifting agriculture that exposes widening areas to erosion and loss of the soil's meager fertility.

During intensive rains, landslides on denuded hillsides claim lives and property [52], and sediment-laden runoff exacerbates flooding. For example, tropical storm Thelma is reportedly responsible for more Philippine deaths, largely by landslides, than the eruption of Mount Pinatubo [17]. Further, removal of coastal shelterbelt forests, such as mangroves, leaves large populations vulnerable to onshore strong winds and tidal surges during tropical storms. Such storms have repeatedly claimed thousands of lives in low-lying areas of Bangladesh.

Rights of Indigenous Peoples

Many tropical forest areas are inhabited by indigenous peoples who practice low-impact subsistence methods of survival. Their numbers are increasing in some places, such that renewability of biological resources is threatened. In other areas, subsistence lifestyles are being displaced by competing, more destructive land uses that give higher short-term returns. Politicians in countries such as the Philippines express growing concern over indigenous peoples' claims to forest land tenure [26]. In addition, legal claims of the forest dwelling people are mired in highly disordered land law in many tropical countries [18].

NGOS and some scientists advocate secure forest land tenure and modified subsistence practices as the basis for the sustainable economic development of indigenous communities and for old-growth forest protection [13]. In most places, however, little scientific effort has been made to determine whether and how tribal practices can be made more productive without degrading natural resources.

Tropical Countries' Mounting Debt Burdens

Conservation becomes increasingly difficult as tropical countries' debts increase. The need for foreign exchange to service debts and rebuild economies provides a strong incentive for national decisionmakers to approve rapid liquidation of exportable timber [8]. Public funds are lacking for direct investment in forest conservation and for investment in job-generating development programs that could relieve the need to convert forests to marginal farmland. Even when low-interest loans are available from international development banks, poor countries are reluctant to add to their debt by borrowing for forest conservation and management projects; such investments are at risk for a long period before payback is realized.

International Trade and the Environment

Although international agreements exist to control or prohibit trade in products from threatened or endangered species (e.g., the Convention on International Trade in Endangered Species), the broader relationship between trade and environment is little understood. Trade may promote competition and thus efficiency in production, thereby reducing waste and, potentially, pollution. Further, some argue that trade sanctions can serve as a strong incentive for countries to institute biodiversity and forest protection policies. Conversely, international trading patterns may increase developing countries' dependence on extraction of natural resources and intensive production of tropical cash crops, hence promoting resource degradation.

The main organization governing international trade agreements and promoting liberalized trade—the General Agreement on Tariffs and Trade (GATT)--has been increasingly criticized for neglect of the environmental consequences of trade. Several international agreements dealing with global environmental problems, on the other hand, contain trade-related measures such as allowing discriminatory treatment of imports that contain stratospheric ozone-depleting chlorofluorocarbons, Some environmental protection measures may be eliminated under current international trade negotiations [63]. In fact, a recent GATT dispute resolution panel ruled that the United States could not restrict tuna imports from Mexico because of Mexico's noncompliance with a U.S. domestic law prohibiting tuna harvest technologies that kill excessive numbers of dolphins [7,55]. National and international conflicts between environmental protection efforts and trade liberalization efforts are likely to increase, with uncertain outcome.

Threats of War and Ecoterrorism

Political unrest and its most extreme expression—war-is a widespread and pervasive threat to tropical forests and biodiversity. Valuable tropical timber, such as Myanmar's (formerly Burma) teak forests, may be harvested at unsustainable rates to fund military actions [41], Forested areas are common sites for militants to hide, and fight. In addition to deliberate efforts to devegetate such areas, as occurred in Vietnam, subsequent actions may compound forest and biodiversity loss. For example, farmers may shift from areas degraded by craters, shrapnel, and live munitions into forested areas. Due in large part to an international trade embargo imposed on Vietnam after 1975, much of its energy is supplied by firewood and charcoal, resulting in further forest loss [28].

Biodiversity in entire ecosystems is threatened by acts of war. Examples include the deliberate oil spills and well frees that have occurred in Kuwait [37]. As biodiversity has been proclaimed an important value to political constituencies in developed countries, it has become a concern during the destruction caused by war and a potential target for terrorist acts. In the United States, forest rangers and endangered spotted owls have become the targets of ''environmental terrorists' protesting restriction of timber harvest to protect the owl's habitat [14], and old-growth trees have been spiked with nails, thus endangering the loggers and sawmillers. Charismatic tropical species—such as gorillas-may be similarly threatened by some people to gain attention or to extort concessions. Conversely, efforts to educate people about the ''world heritage' value of mountain gorillas seems to have fostered special efforts to protect them during recent Ugandan-Ruandan conflicts in the gorilla's habitat [43].

Unintended Impacts of Forest Protection Policies

Because of the diversity of cultural and governmental systems, general policies may, in some places, have counterproductive results. In such countries as the Philippines and India, political momentum is building for logging bans. At the same time, conservation groups in Europe and North America have discovered that forest policies of development assistance organizations are vulnerable to political lobbying. As a result, the World Bank declared it will no longer lend for projects that include cutting natural tropical forests [67]. Consequently, logging may be officially banned in some areas and investments to improve management of production forests may be deferred in others. However, illegal and unmonitored logging may continue [cf: 1], and laborers who previously supported themselves through logging may turn to agriculture in forested areas. Where governments have made tree cutting illegal (e.g., the sal forest area of Bangladesh), forest degradation and deforestation often continues and may even accelerate [68]. Government agencies may not be capable of or motivated to



Photo credit: Walter *E.* Parham, *Office of Technology Assessment*

Although harvest restrictions may be required in many cases to protect tropical forests and the environmental services they provide, total logging bans may lead to illegal "timber poaching" in areas where forests are not monitored.

protect forests that have no readily apparent or immediately accessible economic value.

NEW CONSERVATION APPROACHES

Several new approaches to conservation of tropical forests and natural areas have been developed in recent years. Congress has supported these significantly, but will need to monitor and evaluate them, as the efficacy of most of these approaches is not yet proven.

Development Assistance Focus on Improving Policies

The OTA assessments and similar analyses of tropical forestry and biodiversity problems conducted in the mid- 1980s concluded that government policies-especially land/resource use rights and economic policies (e.g., taxes, prices, equity, and sector development priorities)-strongly foster destruction of forests and their genetic resources. Policy reform was recognized as a necessary condition for effective conservation.

Several influential policy studies [cf:3] in the late 1980s identified specific opportunities for policy reform. The United Nations, with its Tropical Forestry Action Plan (TFAP) program, the multilateral development banks, and AID (especially the Asia missions) all began to develop ways to use development assistance to promote policy reform. Commonly, development assistance agencies conduct policy studies jointly with host governments, often in the context of forestry action plans, forestry master plans, or planning for specific forestry sector assistance projects. Then development assistance agencies encourage the host governments to act on recommendations. For example, funds for development projects may not be released to the host governments until key policy reforms are adopted and implemented.

Tropical Forestry Action Plan

TFAP, initiated in 1985, was designed to help governments: 1) reassess forest development priorities, 2) increase the amount of international investment in forestry, and 3) coordinate forestry sector development assistance funding. The OTA assessment and other reports indicated that poor coordination among donors was an important constraint on efficient use of development assistance from AID and other assistance providers. The United Nations' Food and Agriculture Organization (FAO), together with World Bank, the United Nations Development Programme (UNDP), and the World Resources Institute, developed TFAP to set out development efforts on fuelwood and agroforestry; industrial forestry; research, training, and extension institutions; land use on upland watersheds; and ecosystem conservation. It was estimated in 1985 that investment needs for these aspects of tropical forestry would be $5.3 billion over 5 years.

Development assistance investments have reached nearly 70 percent of the 1985 estimate of needs [67]. The TFAP program stimulated many people and organizations to discuss the causes of and possible remedies for deforestation. About 60 countries decided to prepare national forestry plans (forestry "action" plans in some and forestry "master' plans in others). The plans are beginning to prove effective in coordinating and focusing international forestry assistance. For example, the Forestry Master Plan in Nepal was developed with support from the Asian Development Bank and technical assistance from the Government of Finland. The AID mission in Nepal now is providing technical assistance for the plan's implementation.

TFAP has, however, been criticized heavily. Plans are viewed as too government-oriented and too

focused on harvesting timber as opposed to reducing deforestation. Some NGOs argue that TFAP-sponsored national plans give little consideration to needs and priorities of people living in or near the forests. In addition, some feel the plans do not adequately address institutional weaknesses or government corruption-major causes of forest degradation in some countries.

FAO has undertaken a major evaluation of TFAP [19]. Concerned multilateral and bilateral development assistance agencies are meeting with key tropical governments and NGOs to reformulate the plan's goals, objectives, and procedures. Changes are likely to include improved integration of the national forestry plans with other national planning, increased participation by people whose livelihoods depend on the forests, greater emphasis on multisectoral actions, and increased attention to government policies that directly and indirectly affect forest sustainability [67]. An international consultative group on tropical forests reportedly has been proposed to oversee and advise TFAP and periodically review its impact [19].

The U.S. Government has participated in TFAP through support for FAO and other multilateral sponsors, through AID participation in development of the national forestry action plans and master plans, and through Forest Service and AID participation in efforts to evaluate and revamp the program. The extent to which AID forestry activities are guided by TFAP and the national forestry plans varies from country to country, depending on AID officers' judgments and on the extent to which the host governments use the plans to coordinate donors.

Planning and Coordinating Interventions

Where destruction of genetic resources is imminent, biologists may use structured "rapid appraisal' techniques to focus research and programs on threatened organisms and habitats. For example, the Rapid Assessment program sponsored by Conservation International uses satellite imagery, aerial reconnaissance, and ''quick and dirty' field surveys to inventory species and provide preliminary identification of regions of particular biological richness [45]. The methods can lead to efforts to conserve habitats, rescue genetic resources, or at least capture some material and information of scientiic value before the resource is lost. The techniques developed for this purpose also may help to make scientific investigations more cost-effective on the sites that are not threatened, hastening discoveries that demonstrate the economic potential of biodiversity. This is one of several approaches being used to set priorities for, plan, and coordinate tropical forest and biodiversity conservation projects.

Other approaches focus on conservation planning. The World Bank, for example, has developed biodiversity profiles of numerous countries to assist in project planning and assessment, and is preparing regional strategies to support biodiversity conservation. National Conservation Strategies developed in many tropical countries in recent years have identified policy reforms that can enhance tropical forest and biodiversity conservation.

Debt-for-Nature Swaps

An officer of the U.S. World Wildlife Federation in 1984 proposed a way to use debt reduction to fund environmental protection in developing countries. The mechanism, commonly referred to as "debt-for-nature swaps,' was first applied to Bolivia, Ecuador, and Costa Rica in 1987. At frost, this mechanism could only use commercial debt. Since then, with support from the U.S. Congress and other donor governments (e.g., Germany, England, the Netherlands, Sweden), the approach has been broadened to be applicable to some public debt and has been used to fund nature conservation in African and Asian tropical countries as well. Funding from many such swaps has been used to establish and manage natural forest protected areas. Thus, the biodiversity benefits probably are substantial. Some arrangements have been used to fund other types of conservation and development programs, and the largest have been used as incentives for policy commitments.

The significance of debt swaps for reducing international debt or for meeting the needs for conservation funding seemed modest in mid-1989 [34], when only about $100 million in debt-for-nature swaps had been negotiated. Since then, however, the pace of this activity has increased rapidly. For example, in late 1989 the Government of Germany wrote off $405 million of Kenya's debts in return for commitments to protect the environment. AID initiated a natural resources management program in 1991 that will pay off about $100 million of the Philippines debt as the Philippines Government adopts and implements policies that lead to sustainable tropical forest management. While debt

swaps may become a significant factor in development assistance funding to conserve tropical forests and biodiversity, it is unlikely they will retire a significant portion of developing countries' debts. For 13 countries involved in debt swaps between 1987 and 1990, under one-twentieth of 1 percent of countries' external debts was retired [62].

Most debt-for-nature swaps to date have been arrangements negotiated among the central bank of a developing country, an international NGO acting as broker, one or more public or private donors, a local developing country NGO, and the natural resources agency of the developing country. The international NGO uses money from the donors to purchase the developing country's debt at a discount on the secondary market. The debt is then canceled in return for the debtor nation's commitment to a nature conservation action. Actions might include issuing bonds to produce a stream of funding that can be used for conservation programs implemented by local environmental NGOS, or for establishing and managing nature reserves in forested areas. The approach is flexible, however. Recently, large swaps have been arranged directly between donors and host governments. AID's Natural Resources Management Program in the Philippines combines direct repayment of Philippines' debt with a usual NGO-brokered swap of dollar debt for local currency bonds.

The U.S. Congress has been instrumental in encouraging development of the debt-for-nature swap mechanism. The 1988 Foreign Assistance Appropriations Act ordered the Treasury Department to analyze debt-for-nature arrangements. Treasury issued a ruling that gave U.S. banks a tax incentive to act as private donors in debt swaps [38]. The ruling was modified to increase the incentives after a Senate inquiry. The International Development and Finance Act of 1989 encouraged multilateral development bank involvement in debt-for-nature swaps, authorized AID spending for such swaps, and modified AID practices to allow grantees (e.g., NGOs) to retain the interest on proceeds resulting from the exchanges. Thus, Congress allowed AID funds to be used for exchanges where local currency bonds are issued and where conservation organizations are given endowments rather than just current-year funding. This helps to resolve a significant problem identified in the 1984 OTA assessment: tropical forest conservation needs to be supported by long-term programs, but most development assistance funding has been limited to short-term projects.

Debt-for-nature exchanges are a new and politically appealing form of development assistance. However, most analyses of debt-for-nature swaps do not mention from whose pocket the funds come, and few questions have been asked about grantee accountability, the efficiency of investments made through debt-for-nature swaps, or whether the technologies the finds are spent on are effective. With the stakes getting higher, Congress may consider looking into these issues.

Extractive Reserves and Buffer-Zone Development

Tropical country governments commonly do not have sufficient resources to enforce resource-use restrictions on public lands without the willing cooperation of local people. For at least a decade, environmentalists have promoted resource-use zoning in certain areas, using buffer-zone development and extractive reserves as ways to give local people a stake in forest conservation. Both zoning approaches are based on reducing local peoples' need to use resource-degrading practices in areas of high biodiversity or environmental service. For example, some sites particularly vulnerable to human-induced degradation might be restricted from any human use. In other areas where sustainable wood production and nature conservation are not compatible, only controlled harvests (''extraction") of non-wood products would be allowed. Forests in buffer zones near settled areas would be intensively managed for wood products the local people use. Forests further from settlements would be managed for industrial timber. Extensionists, from forestry departments or from local NGOs, would facilitate local peoples' participation in establishing the restrictions, and the people would enforce the restrictions through social pressure.

Variations of the buffer zone approach are being tried, mostly in small-scale projects developed cooperatively by forest departments and NGOs. An extensive review of these efforts in several tropical countries indicates that most such projects are less than 5 years old, few are large enough in scale to affect a majority of the people living near the subject forest, and most of the NGOs are inexperienced in rural development [65]. Thus, these must be consid-

ered trial efforts and the projects undertaken so far cannot yet be considered successful or replicable.

The only large-scale test of the extractive reserve concept is in Brazil. Rubber tappers and Brazil nut harvesters promoted such reserves as an alternative to timber harvesting and land clearing, and the Brazilian Government has established a legal framework for such reserves. A substantial investment, including development assistance funds, is being made in research and infrastructure, so monitoring and evaluation will probably indicate the degree of success within a decade. This important test of the extractive reserve theory may be undermined, however, by events outside of local or national control, such as low world prices for natural rubber.

Research Reserves and Gene Sanctuaries

Certain tropical forest and other biologically diverse areas have been set aside to advance scientific understanding of ecosystems, and to protect germplasm of economically important species. For example, most biosphere reserves have zones designated for ecological research and management trials. Tropical research stations, such as La Selva (Costa Rica), operated by the Organization for Tropical Studies, and Barro Colorado Island (Panama), managed by the Smithsonian Institution, allow scientists access to undisturbed tropical ecosystems. The United States also has established a system of marine and estuarine sanctuaries which serve as research reserves prohibited from use other than by scientists attempting to understand the dynamics of their ecological systems. The scientific knowledge derived from study of these research reserves likely will provide new insights into ecosystem management.

Scientists who explore tropical forests for new or specific plants continue to introduce new products to U.S. and other markets. For example, out of 85 fruit and nut crops recently brought to the United States from the Malaysian rain forests, six are expected to be introduced to U.S. markets. The plant material from all of these species will be available for research to the U.S. Agricultural Research Service ''regardless of the fate of their native rainforests' [60], Despite their potential contributions to world markets, few forest areas have been set aside specifically to safeguard the genetic resources of crop species. The Indian Government has established a gene sanctuary for citrus plants in the northeastern part of the country. Mexico has established a 350,000 acre biosphere reserve near Guadalajara that safeguards *Zea diploperennis,* a perennial com with genes that provide resistance to several diseases [46].

Development of New Products

The potential that genetic resources hold for the development of new medicines, other new products, and improved agricultural crops is a primary rationale for biodiversity conservation. The OTA assessments reported scientists' expectation that economic botany and ethnobiology research could reveal this potential and thus motivate improved management and conservation of the natural resource base. That expectation has now been reinforced by substantial improvement in the methods for screening natural products for their potential as medicines. Using biotechnology, scientists have isolated receptors and enzymes involved in certain diseases, and many types of diseased cells can now be cultured for use in screening. With robotics, technicians can now screen thousands of samples in the time it took to test 20 to 50a decade ago [48].

New investments are being made in biodiversity research, and probably will lead to new conservation efforts as well. Some 200 companies and nearly as many research institutions worldwide are reportedly looking for plants as sources of pharmaceuticals and pesticides. For example, AID, the National Science Foundation, and the National Cancer Institute have proposed a Joint Program on Drug Discovery, Biodiversity Conservation, and Economic Growth that would provide grants for pharmaceutical development from plants [11]. Another innovative program, coordinated by AID, is the United States-Asia Environmental Partnership, a coalition of U.S. Government agencies, NGOs, businesses, and their Asian counterparts. This includes a Regional Biodiversity Conservation Network that is intended to assist local communities to benefit economically from preservation and use of Asian forest and marine genetic resources [54].

In some cases it is possible to synthesize the active component of a plant-derived drug when it has been isolated, but synthesis has not been technically or economically feasible for some promising compounds [59]. For these, cultivation or sustained harvest from natural populations becomes necessary. Taxol, a drug being investigated for treatment

of cancer, is a current example. Taxol is extracted from the bark of slow-growing Pacific yew trees, and it takes six 100-year-old trees to extract enough drug to treat one patient. Removal of the bark kills the trees. Destruction of the trees has become a problem, even though the drug is still in the research and development stage. U.S. Department of Agriculture scientists are investigating extraction of taxol from yew tree cells and propagation of Pacific yews by tissue culture.

Private fins, research organizations, and environmental NGOs have begun cooperating to develop methods for sustainable harvest of plants that produce medicines and chemicals. The same organizations have begun to search for legal arrangements (commonly called intellectual property rights) by which people in tropical countries could benefit financially from conservation and subsequent commercial development of the genetic potential in their biologically diverse ecosystems. One of the first such arrangements is an agreement between Costa Rica and a large U.S.-based pharmaceutical company. Costa Rica will protect its biota in return for granting exclusive rights to screen plants collected by a Costa Rican National Biodiversity Institute for pharmaceutically active substances. Profits from "chemical prospecting' will be shared, and profits accruing to Costa Rica will be devoted to its national conservation program [22]. Similarly, other companies are relying on the knowledge of shamans (native healers) to assist them in their search for natural drugs. Further, compensating indigenous peoples for their knowledge or protection of resources valuable to companies in the developed world is recognized in the draft Biodiversity Convention to be discussed at the 1992 United Nations Conference on Environment and Development [11]

Consumer Campaigns

A number of conservation organizations and private firms have begun to promote "green" products. Some promotions discourage consumer use of products made with materials believed to damage the environment (such as beef raised on cleared tropical forest areas or tuna harvested in ways that kill dolphins). More proactive promotions urge consumers to buy products made with materials that come from locally managed natural resources (such as Brazil nuts from extractive reserves). The approach is new, and its direct impact on resource conservation has not been assessed, but evidence



Photo credit: J.Tinsley, USDA Forest Service

Taxol, an anticancer drug produced from the Pacific yew tree, was only recentiy discovered. Expanded investigations into the chemical characteristics of marine and terrestrial organisms show promise for development of pharmaceuticals and other products.

exists that the promotions are having indirect beneficial impacts. For example, U.S. consumer preference for "dolphin safe" labeled tuna **may** have induced non-U.S. fishing companies to modifi their harvest practices to comply voluntarily with U.S. marine mammal protection laws.

Numerous European governments have directly restricted use of tropical wood products. The International Tropical Timber Organization is developing a system for rating tropical timber production according to sustainability. The results will be publicized; wood from well-managed tropical forests may be labeled as environmentally "green." Similarly, the Ecological Trading Company (ETC) is negotiating with the World Wide Fund for Nature to "setup an independent monitoring agency which could give a seal of approval to 'acceptable sources [69]. ETC is a tropical timber company that negotiates agreements directly with forest communities, selects individual high-value trees for harvest rather

than clear-cutting, and uses portable sawmills and horse-drawn timber removal. Although definition of ''well-managed' forests and ''acceptable sources' of tropical timber is problematic, certainly consumer campaigns have potential to raise general awareness about conservation.

Ecotourism

Tourism is a potential source of income, including foreign exchange, that can be generated by tropical forest and biodiversity protection. The game parks in East Africa are the best-known example of nature-or ecotourism, but tropical forest parks also are attracting many visitors. Tropical countries worldwide contain some 1,420 individual national parks and other protected areas [6], many of which regularly appear on ecotourism itineraries, and the majority of which were relatively recently designated. Globally, protected acreage now stands at some 175 million hectares; in some countries protected area growth has been particularly dramatic. Costa Rica's network of 55 national and private wildlife reserves cover nearly 20 percent of the country's total land area [6]. Few of these existed before 1973.

By one estimate, nature tourism accounted for between $2 and $12 billion of the $55 billion tourism generated for developing countries in 1988 [25]. Many developing countries, perceiving ecotourism as a more environmentally benign and sustainable alternative to mass tourism, and a potentially lucrative industry, have developed institutions and programs to attract ecotourists. In many Latin American and Caribbean countries, newly passed legislation encourages investment in ecotourism infrastructure [6]. Besides increasing foreign exchange earnings, tourism generates employment and attracts capital for infrastructure development; through this and other "multiplier effects' it can contribute to economic diversification as well as growth [6,15].

Some parks in Thailand generate income that totals 3 to 10 times the cost of park management [12]. Most tourism income does not become available for conservation, however, as it accrues to private sector service providers (e.g., hoteliers). Still, that income can influence politicians to provide larger budgets and increased political protection for parks. At numerous tropical parks, NGOs are experimenting with ways to make ecotourism benefits accrue to local people. AID is sponsoring such efforts in Costa Rica, Indonesia, and other countries.



Photo credit: Alison L. Hess, Office of Technology Assessment

Tourism revenues may provide economic justification for protection of species and habitats. The Kenyan "visitor attraction value" of a single lion has been estimated at $27,000/year; that of a herd of elephants at $81 0,000/year [25].

Despite sparse data, conservationists and economic planners are finding that ecotourism and the revenues it generates, can, in fact, provide an economic rationale for natural resource conservation and wildlife protection policies [49]. This rationale may be the only broadly accepted means of countering efforts to develop these resources for near-term profits-that is, ''economic value must be assigned to ecological resources if these are to be conserved' [10]. Further, ecotourism can be an important part of a more comprehensive conservation and development strategy by "helping to build a constituency necessary for effective policy and action" [23]. As frost-hand contacts with a wild area and its inhabitants increase, so grows the group of advocates for its protection.

Conversely, tourism may deprive indigenous people access to the resource areas they traditionally have used for hunting, fishing, and foraging [15], potentially driving them farther into vulnerable

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ecosystems or into resource-degrading employment. Tourism also is an unstable source of income, subject to widely fluctuating demand scenarios; local economies that rely heavily on tourist dollars can be severely disrupted by a sudden decline in tourist arrivals. More radically, certain terrorist groups have harassed or killed tourists in an effort to destabilize government regimes in countries highly dependent on ecotourism revenues. This has happened, for example, in Kenya, Papua New Guinea, and Peru [43]. Decline in tourism revenues for any of these reasons eventually is likely to reduce the protection afforded to habitats and species.

NEW POLICIES AND PROGRAMS

New information, new concerns, and experimental approaches are surfacing in international efforts to sustain tropical forests and biodiversity. Proposals range from reorienting research, to sweeping changes in international organizations and new, widescale international agreements. Some of the more immediate and far-reaching of these proposals follow.

Endangered Species and Endangered Ecosystems

The 1973 Endangered Species Act (ESA) established a regulatory program specifically designed to protect U.S. species from extinction. Under ESA, species are listed as endangered or threatened solely on the basis of their population and range trends. The act restrains Federal agencies from funding, authorizing, or carrying out any activity that may imperil a species officially listed as endangered and prohibits all citizens from harming, killing, or uprooting such species on public or private kind. Finally, ESA requires the Fish and Wildlife Service or National Marine Fisheries Service, as appropriate, to develop and implement recovery plans for species in danger of extinction. Despite four congressional amendments, ESA has not lost its reputation as the United States' most powerful and rigorous piece of environmental legislation.

ESA comes before Congress for reauthorization in 1992, and undoubtedly will be the focal point for heated debate. Listing of the northern spotted owl, native to old-growth forests in the Pacific Northwest, and subsequent restrictions on logging those forests, has spurred intense debate over regulatory demands affecting land use and property rights. A coalition of agricultural, mining, forest products, and other industrial interest groups is devoting its attention to reducing ESA's power over land-use decisions.

Since 1973, at least 550 species of animals and plants have been listed as endangered or threatened—of these, six are considered recovered and at least seven have been declared extinct [33]. Six-hundred other species are considered endangered, but are not yet formally listed as such. At current staff and funding levels, the Department of Interior's Inspector General estimates it will take 38 to 48 years to move these species through the listing process [61]; another 3,500 species suspected of endangerment but awaiting analysis will not be dealt with for decades. Consequently, numerous conservation biologists and some members of Congress are advocating an ecosystem protection approach that would protect regionally dispersed, ecologically representative communities of species,

The most far-reaching of these proposals is to develop an "Integrated National Biodiversity Policy' within which ESA would function as a ''law of last resort" [39]. Another proposal is to devise a national biodiversity strategy based on representative ecosystems and subsequently to establish a National Center for Biological Diversity [33]. A counterproposal is to require that the values of continuing a species' existence be compared to the economic values of the activities that endanger it, and thereby determine a winner.

Forestry Research

Forestry, agroforestry, and related environmental issues are being incorporated in the mandate of the Consultative Group for International Agricultural Research (CGIAR). the major network of research institutions funded by bilateral and multilateral donors to support development in tropical regions. The International Center for Research in Agroforestry and one other tropical forestry research institution not yet identified will be brought into the system. A new strategic agenda for forestry research will be shared by these 2 institutions and 10 other CGIAR centers that include forestry projects in their research programs. Other progress in forestry research includes establishment of a Special Program for Developing Countries within the International Union for Forestry Research Organizations, and international donor support to the forestry research



Photo credit: Alison L. Hess, Office of Technology Assessment

Forestry and agroforestry have been incorporated in the mandate of the major network of international agricultural research institutions with the addition of the International Center for Research in Agroforestry in Nairobi, Kenya, and one other institution not yet identified.

capacity of national agencies in the developing countries.

It is likely that much of this new activity will continue the pattern of tropical forestry research conducted over the past 30 years, which has been to downplay natural forest management and to focus instead on forest plantations and, more recently, on agroforestry. Several systems for management of natural tropical forests were developed between 1900 to 1960, but little has occurred since then. Meanwhile, research and technology development for tropical forest plantations have achieved wood yields that are now about 10 times the yields from natural forests. High yielding plantations often are mentioned as a means to offset pressure on natural forests. However, this claim is dubious, because forest plantation establishment commonly begins with razing a natural forest [36].

Existing natural forest management systems were developed at least 30 years ago, and only piecemeal information has been gathered on natural forests since then. Several systems are thought to be sustainable, but implementation and monitoring to confirm this is lacking. The comprehensive review of tropical forest management commissioned by the International Tropical Timber Organization (ITTO) states that:

> . . .it is not yet possible to demonstrate conclusively that any natural tropical forest anywhere has been successfully managed for the sustainable production of timber [36].

Existing systems, if rigorously followed, produce low yields of high-value timber over very long rotations. Low yields and low economic returns may be one reason why only about 800,000 hectares of tropical moist forest is being deliberately managed for sustainable production of timber (0.1 percent of tropical moist forest in ITTO countries), whereas about 40 million hectares have been designated as protected areas where timber production is excluded [36].

Multilateral Development Bank Policies

The pace of multilateral bank lending and the nature of bank-sponsored forestry projects have changed dramatically since 1980. Most forestry lending until the 1970s was for extraction of raw materials and development of wood-based industries. World Bank projects in the 1970s reflected the Bank's broadening social goals; many forestry projects were oriented to tree planting for rural development and other longer term purposes. The World Bank's 1978 policy paper articulated the link between social needs and forestry development and became an important model for policy at other multilateral banks. The pace of project startups accelerated in the 1980s, with a larger share of the projects aimed at reforestation, farm forestry, watershed protection, and similar social and environmental purposes (see table 1). Forestry at other multilateral banks evolved similarly: few loans now are made for direct support of wood industries, but many are made to establish plantations. The banks have begun in the past 2 years to develop projects with explicit biodiversity conservation objectives.

Some agriculture and infrastructure development projects financed by the banks have caused destruction of tropical forests and other natural habitat for

Table I—Number of Forestry Projects Financed (Initiated) by the World Bank by Time Period and Type of Project

	Type of Forestry Project		
Period	Industrial	Social	Environmental
1949 -1969 6		0	0
1970 -1979. 18		6	0
1980 -1985 11		16	4
1986 -1990 10		15	7

SOURCE: World Bank Environment Department, Forest Policy *Paper* (Washington DC: World Bank, 1991).

biodiversity. Largely because of congressional insistence, development banks have implemented environmental impact assessment procedures that should help to avoid such damage in future projects. Most recently, the U.S. executive directors of all multilateral banks have been directed by Congress not to vote in favor of any action that:

> . . . would have a significant impact on the environment, unless a summary of the environmental impact of the action has been made available to the director 120 days prior to the vote. Each director, in turn, has the responsibility to make that information available to the public [32].

The effect of these new directives for environmental impact assessment of development bank projects bears monitoring; implementation of these procedures is just beginning, and the motivation for this reform of bank practices has been mainly external.

The World Bank's new Forest Policy Paper [67] heralds continued evolution in the nature of the forestry projects. Effects on forests and biodiversity will apparently be given increased consideration when the Bank undertakes interventions outside of the forestry sector. Within the forestry sector, Bank interventions will emphasize policy reform and institutional strengthening to support forest and biodiversity conservation. The Bank plans to give increased support to international programs, such as the Global Environment Facility,[2] that provide grants or low-interest financing for biodiversity projects. The Bank's forest plantation projects will avoid razing natural forests or usurping farmland. The new policy paper makes a strong commitment to buffer-zone development, support for parks and reserves, and rigorous environmental impact assessment. Political pressure on the World Bank to commit itself to conservation-oriented forestry has come from the U.S. Congress and, more recently, from the governments of Germany and other European nations. The Asian Development Bank has adopted similar policies, focusing much of its forestry lending on reforestation and social forestry programs.

International Tropical Timber Trade

International organizations concerned with tropical forests and biodiversity commonly focus on establishment and management of protected areas. Many tropical country forestry departments and research organizations concentrate development efforts on forest plantations. ITTO, however, is the one international organization that concentrates on trade and commodities coming from all forests in tropical nations.

The main outcome of the International Tropical Timber Agreement, which became effective in 1985, was a framework for cooperation between nations that produce tropical timber and those that import it. The agreement set up the International Tropical Timber Organization. ITTO has objectives typical of a commodity trade group (e.g., regulation of prices and supplies), but a growing focus of its activities has been analyzing the sustainability of tropical forest use and promoting policy and program changes that would extend sustainable forest management and would develop technical improvements in management systems. Unlike other commodity organizations, meetings to set ITTO policy include representatives from conservation organizations and academia in addition to government and industry representatives.

ITTO's producer members control roughly 70 percent of the world's tropical moist forests [36]. The organization commissioned a major review of forest management for timber production in its member nations, and concluded that the conditions necessary for successful management to sustain production forests are:

[2] The Global Environment Facility (GEF) is operated by the World Bank on behalf of its founders, the U.N. Development Programme and U.N. Environment Programme. GEF is expected to provide "several hundred million dollars" for biodiversity research and protection over the next 3 years [27].

- government resolve;
- a sound political and social case for the decision to maintain a permanent forest estate;
- long-term security for the forest estate, once chosen;
- stable markets for forest products;
- adequate information for selection, planning, and management of the forest estate;
- flexible, predictive systems for planning and control;
- the resources needed for control; and
- the will needed by all concerned for effective control [36].

International Environmental Security

Since the 1980s, the concept of environmental or ecological security, based on the premise that threats to the environment are as serious to human quality of life as military threats [16], has been the focus of considerable discussion related to international environmental law. In a 1989 letter to the United Nations, international ecological security was described as:

> [A] state of affairs in international relations within which a system of. . broad co-operation on the basis of international law will safeguard preservation of the environment and improvement of its quality with a view to creating appropriate conditions for a life worthy of human beings and securing sustainable and safe development of all States [44].

An international legal basis for establishing environmental security as a guiding principle was established in the World Charter for Nature [53]. This document states that:

> . . .nature shall be respected and its essential processes. . not. . impaired [Article 1]; living resources shall not be utilized in excess of their natural capacity for regeneration, the productivity of soils shall be maintained or enhanced, [and] nonrenewable resources. . shall be exploited with restraint [Article X; and] nature shall be secured against degradation caused by warfare or other hostile activities [Article V; and] military activities damaging to nature shall be avoided [Article XX] [66].

Recognition of international environmental security as a guiding concept for intergovernmental relations, however, likely would require codification of international environmental laws. One framework for codification would be to establish two primary categories of environmental management problems.

1. Problems associated with *protection* of the environment: a) avoidance of vandalism (wartime or other non-remunerative destruction); b) avoidance of pollution (of air, water, or soil) that is in excess of the natural renewal or cleansing processes; and c) avoidance of permanent anthropogenic intrusion in specially designated protected areas; and
2. Problems associated with *utilization* of the environment: a) avoidance of resource use rates that exceed estimated maximum sustained yield or maximum sustained absorption; and b) avoidance of resource use at rates that will prevent recovery of degraded environments (and potentially provision of human assistance to aid that recovery) [66].

Creation of such a state of affairs would require the "espousal of obligatory principles and norms of conduct for governments' [50] and, thus, likely would require reconsideration of the realms of national sovereignty and international cooperation. Because of the acknowledged ''globalization" in areas such as production, trade, investment, communications, and tourism, this type of redefinition already is occurring [40]:

> In many crucial respects, nations are no longer the sole masters of their destinies. . . .What happens in practically any part of the world can affect remote areas elsewhere. This interdependence in economic, military, and environmental affairs has already begun to erode traditional notions of security and even national sovereignty itself.

Regional and international mechanisms to progress toward international environmental security already exist, and have shown progress towards international environmental accords. Regional mechanisms take such forms as multilateral and bilateral agreements, international commissions, or licensing arrangements. One prominent example is the United Nations Regional Seas Program, which brokers agreements among countries sharing ocean basins such as the Mediterranean and Caribbean Seas (e.g., Convention on Land-Based Sources of Pollution in the Caribbean).

International mechanisms are likely to be conventions, agreements, charters, or guiding principles promulgated by such institutions as the United Nations and the former Warsaw Treaty Organization. International legal principles address and define international environmental problems and

solutions; international agreements legally bind parties, creating rights and obligations concerning the regulated resources [42].[3] Such efforts already have brought us the World Charter for Nature, the Convention on Trade in Endangered Species, and the unfinished Convention on the Law of the Sea. The latter exemplifies the difficulties in reaching such accords. Further, international organizations that deal with environmental issues commonly lack the capability, or the authority, to ensure adherence with international agreements [44]. For example, the Governing Council of the United Nations Environment Programme (UNEP) has only the powers or recommendation, and not of enforcement. Proposals to remedy this range from enhancing development of regional environmental agreements and organizations [66], to strengthening coordination of environmental concerns at the United Nations and directing UNEP to spearhead codification of international environmental law, to establishing a U.N. Environmental Security Council (requiring amendment of the U.N. Charter) [44].

Expanding International Environmental Accord

The arena for current negotiations on international law related to biodiversity, climate change, and tropical forests is the United Nations Conference on Environment and Development (UNCED or ‘ ‘Earth Summit’ to be held in Rio de Janeiro, Brazil in June 1992. Government negotiators representing developed and developing countries have been meeting for over a year to determine the content and wording of new international charters, statements of principles, and agreements. In addition, and unlike previous international environmental summits, nongovernmental organizations have played a significant role in preparation of documents and introduction of issues into negotiations. The negotiations have been fraught with controversy, largely over “North-South” responsibility for financing conservation efforts [cf:35]; the United States’ position currently is unclear.

The UNCED Intergovernmental Negotiating Committee (INC) on Biodiversity is working toward reaching an agreement that would be signed at the June 1992 “Earth Summit. ” Topics of particular concern to the negotiating parties are financing of biodiversity conservation in developing countries,



f%oto credit:A. Fullerton, USDA Forest Service

The search for medicines from plant and animal sources is most cost-effective when scientists focus on traditional medicines, such as those sold by traditional medicine vendors in China. With the surge in “chemical prospecting,” however, UNCED negotiators have faced increasing controversy surrounding access to genetic materials, product patenting and distribution of royalties, and “intellectual property rights.”

biotechnology and intellectual property rights, and the potential for a sweeping international treaty to ‘‘interfere with individual nations’ authority to manage resources or protect domestic biodiversity. The INC on Climate Change also has faced considerable controversy about provision of ‘‘new and additional’ resources to assist developing countries to meet the objectives of the treaty, which specifies targets and timetables for reduction in carbon dioxide and other greenhouse gases.

A nonbinding statement of “Principles on World Forests” is in preparation for UNCED, but is not presently under negotiation in the form of an international agreement. Instead, it is one component of Agenda 21, an overall environment and development agenda for the future. Still, negotiations on world forest principles have led to agreement on some basic points, that may in the future become the basis for a legally binding convention. As currently agreed, the principles should:

- cover all types of forests;
- establish sustainable management as the goal of forest management;

[3] In the absence of international agreements, global resource regulation is based on the rules and principles of international customary law.

- identify ''social, ecological, cultural and spiritual needs, as well as economic" goals of management;
- strengthen national-level forest management institutions;
- recognize the value of environmental services of forests, including protecting biodiversity and regulating watersheds and water resources;
- respect sustainable use by ''forest dwellers, indigenous peoples, and local communities;
- foster forest management plans based on complete cost and benefit accounting; and

encourage development of an international economic climate that supports sustainable forest development in all countries [47].

Discussion of a Forest Convention is expected to be reopened, likely during the 1992 renegotiation of the International Tropical Timber Agreement, potentially leading to a single international legal instrument on forests [20].

Partly in preparation for development of the UNCED Principles on World Forests, the Tenth World Forestry Congress, involving forestry decision-makers from 136 countries, passed The Paris Declaration (box B) and produced a set of detailed conclusions and recommendations [51]. The principles stated in the Paris Declaration are intended to contribute to the debate leading to UNCED and beyond.

CONCLUSIONS

Significant progress has been made in mobilizing international assistance finding and in coordinating and focusing international conservation efforts in the years since OTA assessed technologies to maintain biological diversity and to sustain tropical forest resources. The stage for forest conservation is being set at high government levels with development of national action plans that set new priorities and call for new programs, institutional development, and major policy reforms. Conservationists behind the planning process are learning to develop necessary links to policies and programs in other sectors, such as population, agriculture, and rural development.

Box B—Excerpts From the Paris Declaration

The Tenth World Forestry Congress, having assembled more than 2,500 participants from 136 countries from 17 to 26 September 1991;

addressees] the public, political leaders and international, intergovernmental and non-governmental organizations throughout the world

reminds them

- of the importance of the renewable goods and services provided by trees and forests in the face of growing demand for construction materials, fuel, animals, food, fodder, recreation areas. . .;
- of the wealth and diversity of forest environments, and of their positive role in water and carbon cycles, soil protection and the conservation of biodiversity;
- of the availability, too often ignored, of techniques for the sustainable management of trees and forests, which can ensure their permanence and even increase their capacity for providing goods and services;
- that it is essential to avoid irreversible darnage to the biosphere; and
- of the advantages of long-term planning in the management of natural resources;

asserts

- that the real challenge is to reconcile the economic use of natural resources with protection of the environment through integrated and sustainable development;
- that the solution of forest problems requires common efforts to reduce poverty; increase agricultural productivity; guarantee food security and energy supplies; and promote development;

that forest management plans can be used as comprehensive took for managing the economic, ecological, social and cultural functions of the resource, thus enlarging the concept of sustain yield;

- that the preservation of specific forest areas in order to protect biodiversity constitutes a particular objective of forest management policy;

(Continued on next page)

Box B—Excerpts From the Paris Declaration-(Continued)

and recommends

- **that all people be involved in the integrated development of their region, and that they be provided with the institiutional technical and financial means to do so;**
- **that land-management planning be based on the land's potential and on long-term priorities in order to determine sites that are best suited to be forest@ and that the needs of all people concern~ particularly those who depend on forests for their livelihood should becarefully taken into consideration at the planning stage;**
- **that the continuity of tree and forest management policies be guarant~ given the need to manage forests on a long-term basis;**
- **that the designation of certain representative or endangered forests as protected zones continue, and that these areas be integrated into national or international networks;**
- **that appropriate silvicultural techniques, the extension of woodlands and the long-term use of wood be used to contribute to the absorption of atmospheric carbon dioxide;**
- **that agroforestry systems, afforestation and reforestation be developed more actively.**

The Tenth World Forestry Congress aware of the seriousness, the urgency and the universality of development and environmenttal problems; emphasking the renewable nature of forest resources and convinced of the soundness of solutions afforded by sustainable management of all the world's forests, within the context of national forestry policies,

solemnly calls upon decision-makers to:

- ***commit* themselves to the "Greening of the World" through afforestation, reforestation and sustainable management of the multiple functions of trees and forests; and to actions in the form on integrated programmed, involving the participation of all people concerned, in the context of national land management policies;**
- **assess developments in the forest heritage at a national and international level, drawing on the global Forest Resources Assessment 1990 Project carried out by FAO;**
- **limit all emissions of pollutants that damage forests;**
- ***contain* emissions of greenhouse gases, including those produced by power generation;**
- **adapt economic and financial mechanisms to the long-term approach required for forest management, and *increase* national and international financial provisions, particularly in favour of developing countries;**
- ***work* toward the harmonious development of international trade in forest products through the prohibition of any unilateral restriction that is inconsistent with GAIT; and promote the utilization of forest products;**
- **develop cooperative initiatives at the political level and on clearly identified forestry issues of regional importance, such as the fight against desertification the protection of forests, the management of major watersheds, etc.;**
- ***strengthen* and *coordinate* research and field trials, training and the exchange of information, as well s cooperation in all disciplines that contribute to sustainable management of forest ecosystems;**
- ***strengthen the activities* of and coordination among the relevant international organizations;**
- ***integrate its* conclusions and reccomendations into the planning process of the United Nations Conference on environrnent and Development (UNCED), to be held in Rio de Janeiro in 1992, in order to define a non-legally authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forrests;'**

and, in the context of the current negotiations on biodiversity and climate change being conducted under the auspices of the United Nations;

- ***strengthen* international cooperation,** particularly in the context **of the** Tropical Forestry Action Programme (TFAP), **of a Mediterranean FAP and of other future programmes;**
- **raise awarenes of the public, and more particularly of young generations, and disseminate information on forest issues so they will be better appreciated by all people;**
- **envisage** ways **of** following **Up its recommend&MM and** invite **FAO to advise the appropriate intergovernmental bodies and the Eleventh World Forest Congress of them.**

SOURCE: ***Unasylva*, "Tenth** World Forestry **Congress—Dossier,"** vol. 43, No. 1, Winter 1992, **pp.** 3-9.

Significantly less progress has been made on the ground. Development of practical methods for management and conservation of forests and biodiversity has been slow. Although forest management is highly site specific, general principles and systems can be adapted to different situations. For 30 years, however, scant attention has been given to imple menting tropical forest management systems, improving them, or developing new ones. NGOs have begun innovative projects in and around tropical forest protected areas. Monitoring and evaluation of these will lead, gradually, to methods for involving local people in integration of tropical forest conservation and development. Other aspects of forest protection are being neglected, however, such as preventing government corruption that allows tree cutting and land clearing not sanctioned by management plans.

The existing (old) systems for sustainable management of tropical forests impose severe restrictions on use of the resources, so opportunity costs of sustainable management are high. Although the benefits would also be high when environmental effects such as biodiversity conservation are included, the opportunity costs accrue directly to citizens of tropical nations while the benefits are spread over global populations. Little scientific effort is directed to increasing the direct financial benefits from sustainable management of natural forests to local communities. Meanwhile, the major underlying cause of deforestation and species extinctions—lack of alternative employment opportunities for rapidly growing populations of tropical countries—remains. Hence, the forests and their biodiversity are still in jeopardy, despite momentum at the international and national policy and planning levels.

Numerous tropical countries now have national plans establishing goals and priorities for biodiversity conservation and forest management, and major programs to reform and implement improved forest sector policies have begun. Concern for biodiversity continues to grow, promoted by international assistance agencies and local NGOs through biodiversity conservation planning and through site-specific projects. The implementation of these plans and programs will succeed or fail in the next 5 to 10 years. Strong momentum for conservation-oriented development assistance exists in the United States and other donor countries. The bilateral and multilateral assistance agencies have **accepted** forceful mandates to promote forest and biodiversity conservation. International technical and financial assistance will be a necessary but hardly sufficient condition for success.

Implementation of policy reforms requires secure commitments from national leaders, sufficient technical knowledge and skills, and continued momentum from grassroots supporters. Yet issues that have not been adequately addressed include the capability of technologies to achieve the goals over the long term, the ability of government agencies and NGOs to control corruption that undermines management plans, and the ways in which forestry and biodiversity use and conservation are linked to other economic and political sectors.

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Technologies to Sustain Tropical Forest Resources

Foreword

The United States has a stake in the sustained economic development of tropical nations for humanitarian, political, and economic reasons. To a great extent, the development of these nations depends on increasing production from their potentially renewable soil, forest, and water resources. But tropical forest resources, which cover nearly one-half of the tropical nations' land, are being consumed at a rate that may make them nonrenewable. They are exploited for timber and cleared for pasture and cropland with little regard for their abilities to produce important goods, maintain soil productivity, regulate water regimes, or regenerate themselves in a long-term sustainable fashion.

International recognition of the importance of tropical forest resources and efforts to sustain the productivity of these resources have increased significantly in the last decade. In 1980, the House of Representatives, Committee on Foreign Affairs, Subcommittee on International Organizations held hearings on tropical deforestation. The committee then requested the Office of Technology Assessment (OTA) to conduct a more thorough assessment of the problem, the technologies that could help sustain tropical forest resources, and possible options for Congress. The Subcommittee on Insular Affairs of the House Committee on Interior and Insular Affairs and the Subcommittee on Environmental Pollution of the Senate Committee on Environment and Public Works endorsed the request. The Senate Committee on Energy and Natural Resources asked that the assessment specifically address forest resources of the U.S. insular territories in the Caribbean and western Pacific.

This summary presents the study's major findings. The full report and its two background papers *(Reforestation of Degraded Lands* and *US, and International Institutions)* identify and discuss in depth some of the constraints and opportunities to develop and implement forest-sustaining technologies.

OTA greatly appreciates the contributions of the advisory panel and workshop participants assembled for the study, the authors of the commissioned technical papers, and the many others who assisted us, including liaisons from other Government agencies. As with all OTA studies, however, the content of the report is the sole responsibility of the Office of Technology Assessment.



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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The **panel** does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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INTRODUCTION

Forests of various kinds cover 42 percent of the tropical nations' land (fig. 1). To support a population of 2 billion[1], these nations must use the natural resources found in these forests: soil, water, plants, and animals. The productivity of these resources can be renewable, but only if tropical people use resource-sustaining technologies.

Some tropical nations are experiencing severe shortages of forest products and services. To avoid even more acute problems, they need to restore resource productivity. Other nations, even those with adequate forests, need to sustain their forest resources to avoid future problems. In just 30 years, the population of tropical nations is expected to double to 4 billion people.[2] Thus, the importance of tropical forest productivity is increasing as more and more people depend on forest products and services for basic needs such as fuel, materials for shelter, and a reliable water supply.

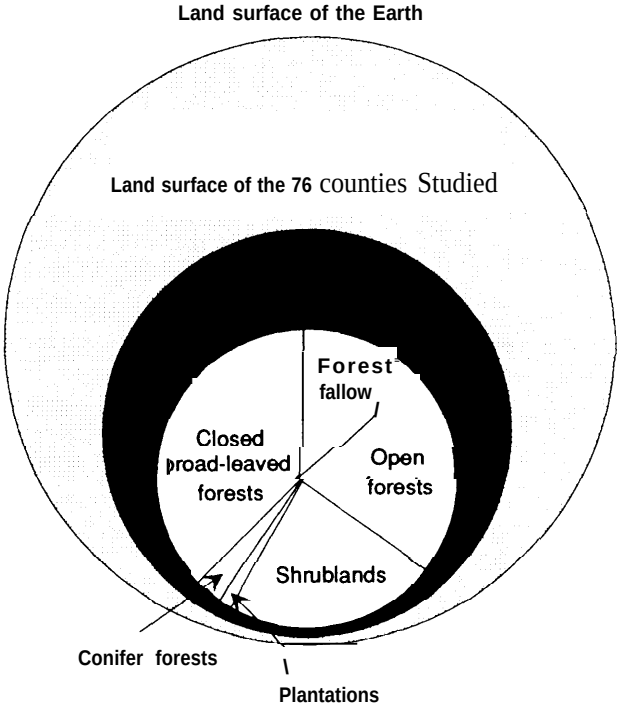
Substantial institutional activity is occurring worldwide that directly or indirectly benefits tropical forest resources. The U.S. Agency for International Development (AID), the United Nations agencies, the multilateral development banks, and others have increased their attention to forestry in recent years. Private corporations and nonprofit organizations also have been involved in the search for solutions to tropical forest problems. Most importantly, tropical nations' governments have come to recognize that deforestation and forest resource degradation constrain their economies and their development options.

The large number of organizations that has some responsibilities in forestry might imply an adequate level of activity is underway. But the total amount of expertise and funding available to forestry still remains small relative to the scope of the problem. International development assistance organizations cannot fund enough forest conservation to offset deforestation because the underlying institutional causes can only be resolved by the tropical countries themselves.

IMPORTANCE OF TROPICAL FOREST RESOURCES

For tropical nations, forests and shrublands provide wood for lumber and paper, building materials, and fuel, and are an important source of foreign exchange. Forests help maintain soil quality, limit erosion, stabilize hillsides, modulate seasonal flooding, and protect waterways and marine resources from accelerated siltation. In addition, many millions of people living in and near the forests depend

Figure I-Global Areas of Tropical Woody Vegetation



SOURCE: M. Hadley and J.P. Lanley, "Tropical Forest Ecosystems: Identifying Differences, Seeking Similarities," Nature *and Resources*, UNESCO, 19(1):2-1 9,1983.

[1] In the seven years since the OTA's report on tropical forest resources was written, the population of tropical nations (excluding China, including India) grew to 2.4 billion, an increase of 17 percent [C. Haub, et al., "1991 World Population Data Sheet" (Washington, DC: Population Reference Bureau, 1991)].

[2] The tropical nations' population is now expected t. reach 4 billion in the year 2015 [C. Haub, et al., "1991 World Population Data Sheet" (Washington, DC: Population Reference Bureau, 1991)].

directly on them for food, medicines, and other basic needs.

The benefits from tropical forests are not limited to tropical nations. World trade in tropical wood is significant to the economies of both the producing and consuming nations. The United States is the second largest importer of tropical wood products and U.S. demand for tropical wood has been growing at rates well above our population and gross national product growth rates. Tropical forests also provide a broad array of nonwood products such as oils, spices, and rattan that are valuable for both subsistence and commerce. The annual world trade in rattan, for example, is estimated to be $1.2 billion. Thus, industrial wood and other forest product exports earn substantial foreign exchange for nations that trade with the United States.[4]

The productivity of renewable resources in the Tropics affects both the economic viability of U.S. investments overseas and political stability in the tropical nations. Many development projects funded by the U.S. Government or the U.S. private sector are being undercut by flooding, siltation of reservoirs, pest outbreaks, and other problems associated with deforestation. Food and jobs, both critical for political stability in developing nations, can be reduced by the consequences of deforestation.

The highly diverse tropical forests contain plants, animals, genetic material, and chemicals that have great potential value for medicine, agriculture, and other industries. The Tropics are thought to contain two-thirds of the world's approximately 4.5 million plant and animal species. An estimated 2.5 million of the tropical species are yet unknown to sciences Considering the value to society that has come from those tropical species that have been studied (e.g., many major agricultural crops, anticancer drugs, insects used in integrated pest management), it is very likely that some of the remaining unstudied species offer potentially important resources, particularly for pest control, plant breeding, genetic engineering, and other biotechnologies. Biologists are already using new techniques for cloning plants and microorganisms to screen existing organisms for their production of useful chemicals.

Tropical forests also provide habitats for many of the world's migratory birds and various endangered species. About two-thirds of the birds that breed in North America migrate to Latin America or the Caribbean for winter. Some of these migratory birds play an important role controlling agricultural pests in the United States.

STATUS OF TROPICAL FORESTS

Some *76* nations located entirely or largely within the tropical latitudes contain about half the world's population (approximately 2 billion).[6] These nations are characterized by rapidly growing populations, low per capita incomes, and predominantly agrarian economies. Near forest lands, much of the agriculture is subsistence farming, often in upland areas where soils are dry or have low fertility. Commercial agriculture, on the other hand, generally is sited on the more fertile and often irrigated alluvial plains of major river valleys. Both types of agriculture are strongly affected by the 1.2 billion hectares[7] of moist tropical forest and 800 million hectares of drier open woodlands.

The type and distribution of forests vary considerably across regions in the Tropics (fig. 2). Two-thirds of the closed forests[8] are found in tropical

3 In 1989, the United States ranked as the major developed country importer of two unfinished wood products from developing countries, wood pulp and fiberboard, both coming mostly from Brazil. It also ranks as a major importer of sawn hardwood (from Brazil), veneer sheets (from Brazil and the Philippines), and plywood (from Indonesia). However, Japan far outranks the United States as an importer of these and other developing country wood products [United Nations, Food and Agriculture Organization, "Forest Products Yearbook: 1978 -1989," Rome, Italy, 1991].

4 In 1985, the major tropical wood exporting nations have joined the major importing nations in the International Timber Trade Organization (ITTO), which is unique among commodity trade groups in that conservation of the resource base is a major focus of its activities. (See introduction.)

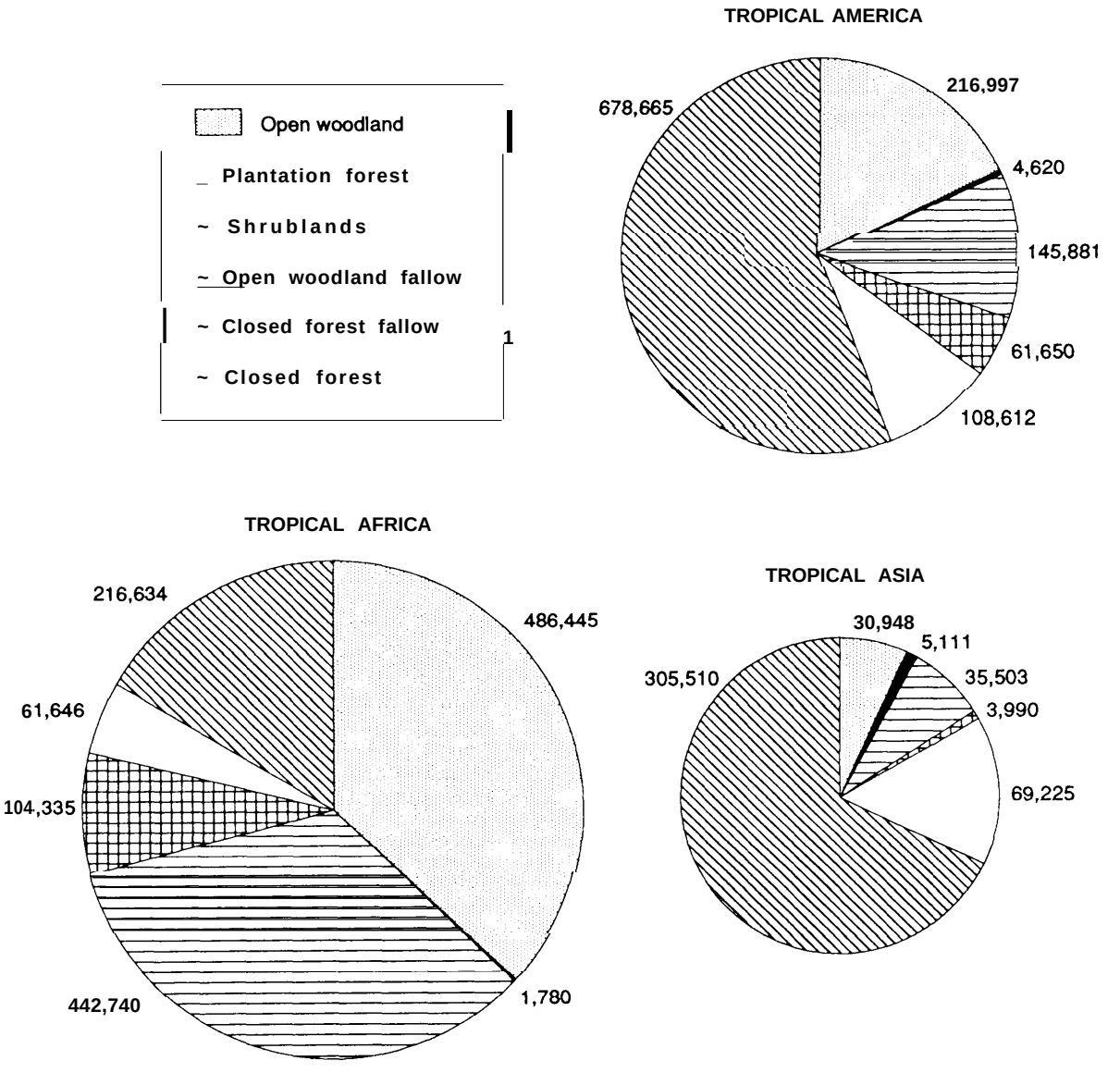
5 Estimates of the number of species have been revised upward in recent years. Taxonomists have described and named about 1.4 million species; the total number of species now is estimated to range from 10 to 30 million. Most of these reside in tropical forests and are likely to become extinct before they are described [E.O. Wilson, "The Current State of Biological Diversity," *Biodiversity* (Washington, DC: National Academy Press, 1988); J.A. McNeely, et al., *Conserving the World's Biological Diversity* Gland, Switzerland and Washington DC: International Union for the Conservation of Nature and Natural Resources, 1990)].

6 In mid-1991 the 76 nations' population was approximately 2.4 billion [C. Haub, et al., "1991 World Population Data Sheet" (Washington, DC: Population Reference Bureau, 1991)].

7 One hectare equals 2.4 acres.

8 Closed forest means that trees shade so much of the ground that a continuous layer Of grass cannot grow.

Figure 2—Areas of Woody Vegetation[a] in 76 Tropical Nations (thousands of hectares, 1980 estimates)



[a]Closed forest has dense tree canopies and noncontinuous grass cover. Open forest has scattered trees and continuous grass cover. Forest fallow is land used for or abandoned from agriculture. Shrubland has woody vegetation under 7 meters high.

SOURCE: Office of Technology Assessment.

America, while Africa has two-thirds of the open forests.[9] Even within regions, forest types are unequally distributed among countries.

Data on the extent and condition of tropical forests are widely scattered and often inaccurate. Overall figures for deforestation[10] mask consider-

9 Open forest has trees that cover at least 10 percent of the ground but still allow enough light to reach the forest floor so that a dense, continuous cover of grass can grow.

10 Deforestation is the conversion of closed o, open forest to nonforest. A distinction should be made between deforestation and degradation; the latter refers to biological, physical, and chemical processes that result in loss of the productive potential of natural resources in areas that remain classified as forest. This distinction explains some of the confusion in estimates of change in forest resources.

Table 1—1985 Estimates of Closed Forest Areas and Deforestation Rates in Tropical Africa, America, and Asia

Country	Closed forest area (1,000 ha)	Percent deforested per year
Tropical Africa:		
Ivory Coast	4,458	6.5
Nigeria	5,950	5.0
Rwanda	120	2.7
Burundi	26	2.7
Benin	47	2.6
Guinea-Bissau	660	2.6
Liberia	2,000	2,3
Guinea	2,050	1.8
Kenya	1,105	1.7
Madagascar	10,300	1.5
Angola	2,900	1.5
Uganda	765	1.3
Zambia	3,010	1.3
Ghana	1,718	1.3
Mozambique	935	1.1
Sierra Leone	740	0.8
Tanzania	1,440	0.7
Togo	304	0.7
Sudan	650	0.6
Chad	500	0.4
Cameroon	17,920	0.4
Ethiopia	4,350	0.2
Somalia	1,540	0.2
Equatorial Guinea	1,295	0.2
Zaire	105,750	0.2
Central African Republic	3,590	0.1
Gabon	20,500	0.1
Congo	21,340	0.1
Zimbabwe	200	[b]
Namibia	[b]	[b]
Botswana	[b]	[b]
Mali	[b]	[b]
Upper Volta	[b]	[b]
Niger	[b]	[b]
Senegal	220	[b]
Malawi	186	[b]
Gambia	65	[b]
Totals	216,634	0.61
Tropical America:		
Paraguay	4,070	4.7
Costa Rica	1,638	4.0
Haiti	48	3.8
El Salvador	141	3.2
Jamaica	67	3.0
Nicaragua	4,496	2.7
Ecuador	14,250	2.4
Honduras	3,797	2.4
Guatemala	4,442	2.0
Colombia	46,400	1.8
Mexico	46,250	1.3
Panama	4,165	0.9
Belize	1,354	0.7
Dominican Republic	629	0.6
Trinidad and Tobago	208	0.4
Peru	357,480	0.4
Brazil	357,480	0.4
Venezuela	31,870	0.4
Bolivia	44,010	0.2
Cuba	1,455	0.1
French Guiana	8,900	[b]
Surinam	14,830	[b]
Guyana	18,475	[b]
Totals	678,655	0.6
Tropical Asia:		
Nepal	1,941	4.3
Sri Lanka	1,659	3.5
Thailand	9,235	2.7
Brunei	323	1.5
Malaysia	20,995	1.2
Laos	8,410	1.2
Philippines	9,510	1.0
Bangladesh	927	0.9
Viet Nam	8,770	0.7
Indonesia	113,895	0.5
Pakistan	2,185	0.3
Burma	31,941	0.3
Kampuchea	7,548	
India	51,841	...
Bhutan	2,100	0.1
Papua New Guinea	34,230	0.1
Totals	305,510	0.6

[a]From 1981-85.
[b]No data; in most cases this is where the areas are very small.

SOURCES: Food and Agriculture Organization/United Nations Environment Programme, "Tropical Forest Resources Assessment project (GEMS): Tropical Africa, Tropical Asia, Tropical America," 4 vols., Rome, 1981.

able differences among the rates at which individual countries are using and altering their forest resources (table 1). If present trends were to continue, nine tropical countries would eliminate practically all of their closed forests within the next 30 years and another 13 countries would exhaust theirs within 55 years.[11]

Estimates of overall deforestation rates also conceal significant differences in the types of tropical forest affected. The loss of species is

[11] Data summarized in Figure 2 and Table 1 are taken from the FAO/UNEP assessment of tropical forest areas for 1980. The FAO undertook a new assessment to update the data to 1990. The results, summarized in Table 2, are considered more accurate than the earlier assessments. They indicate that the deforested area from 1981 to 1990 averaged 16.9 million hectares per year. This is a significant increase over the 11.3 million hectares per year estimated for 1976-80 [United Nations, Food and Agriculture Organization, "Second Interim Report on the State of Tropical Forests," Presented to the 10th World Forestry Congress, Paris, September 1991].

Table 2—1991 Estimates of Tropical Forest Area and Deforestation Rate for 87 Countries in the Tropical Region (area figures are millions of hectares)

Countries studies (#)	Total land area	Forest area 1980	Forest area 1990	Area deforested annually 1981-1990	Rate of change percent per year
Latin America					
Central America and Mexico (7).	245	77	64	1.4	-1.8940
Caribbean Sub-Region (8)..	70	49	47	0.2	-0.4
Tropical South America (7).	1,361	797	729	6.8	-0.8
Subtotal, Latin America (32)..	1,676	923	840	8.4	-0.9
Asia					
South Asia (6).	446	71	66	0.4	-0.6
Continental Southeast Asia (5).....	193	83	70	1.3	-1.6
insular Southeast Asia (4).	258	157	139	1,8	-1.2
Subtotal, Asia(15).	897	311	275	3.5	-1.2
Africa					
West Sahelian Africa(8)	528	42	38	0.4	-0.9
East Sahelian Africa (6).	490	92	85	0.7	-0.8
West Africa (8).	203	55	43	1.2	-2.1
Central Africa (7).	406	230	215	1.5	-0.6
Tropical Southern Africa (lo).	558	218	206	1.1	-0.5
Insular Africa (l).	58	13	12	0.2	-1.2
Subtotal, Africa (40).	2,243	650	600	5.1	-0.8
Total (87).	..4,816	1,884	1,715	17.0	41.9Y0

SOURCE: United Nations Food and Agriculture Organization, "Second Interim Report on the State of Tropical Forests," Presented to the loth World Forestry Congress, Paris, France, September 1991.

probably greatest in the broad-leaved humid lowland forests, as these are biologically the most complex and diverse. But the tropical conifer forests cover much smaller areas and have been severely degraded by logging and agriculture. Direct impacts on people are greatest in dry regions where degradation of open forests leads to severe shortages of wood for fuel. But the loss of mountain watershed forest may affect even more people by making river flows more erratic.

Each year approximately 11.3 million hectares of the Earth's remaining tropical forests-an area roughly the size of Pennsylvania-are cleared and converted to other uses.[12] were cleared land is developed for sustainable agriculture, deforestation can be beneficial. But most land being cleared cannot sustain farming or grazing with available technologies, so it is abandoned after a few years. Often, commercially valuable trees do not grow back quickly because of highly weathered soils, harsh climates, and recurring fires. Thus, highly productive but underused forest resources are giving way to low-productivity grasslands and deserts.

Deforestation and degradation of tropical lands are not new. losses of forest resources have been reported as early as 450 B.C. in the African Sahel and 1000 A.D. in South China. For centuries, tropical deforestation has been associated with poverty and with patterns of economic development that result in inequitable access to farmland. People displaced by development in the lowlands often have been the direct agents of deforestation because they have little choice if they are to survive.

The main agents of tropical deforestation and forest resource degradation continue to be subsistence agriculturalists, livestock raisers, fuelwood collectors, and people who set fries to facilitate clearing or gathering activities. Commercial agriculture plays a smaller role in deforestation today than it has in the past, although in some areas (e.g., Central America and Brazil) clearing tropical forests for cattle ranching causes a large part of the forest resource loss. Commercial logging is also an important cause of forest degradation.

Subsistence and commercial use of forest lands can cause deforestation. Combined, they form par-

12 The average area of tropical forest deforested annually from 1980-1990 was 17 million hectares [United Nations, Food and Agriculture Organization, ''Second Interim Report on the State of Tropical Forests,' Presented to the 10th World Forestry Congress, Paris, September 1991].

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ticularly pernicious relationships. For example, loggers build roads through undisturbed forests to remove timber. Slash-and-bum cultivators use the roads to gain access to the forests and clear patches for temporary agriculture. Ranching or commercial agriculture may follow the farmers, exploit the land's remaining productivity, then move on into new areas. These agents of tropical forest change vary in prominence among tropical America, Africa, and Asia.

Alternative techniques exist that could be substituted for these destructive practices. However, sustainable forestry and agriculture practices generally are not being developed and applied. The underlying causes of this failure lie in political, economic, and social forces (e.g., undefined property rights) that cause people to use forests in ways that are inappropriate to ecological conditions. Deterioration of the forest resources seems likely to continue until combinations of improved technologies and enforced resource development policies make sustaining the forests more profitable than destroying them.

TECHNOLOGY ASSESSMENT

This report discusses various technologies to develop tropical forest resources. Some are techniques to manage forests—undisturbed and disturbed-and some are technologies to use forests to protect related resources such as agriculture and water. Others are techniques to prepare people for the various tasks involved in developing and implementing technologies to sustain the resources.

Technologies for Undisturbed Forests

Undisturbed forests produce many valuable products and services, usually with little or no human management. One way to reduce the rate at which undisturbed forests are converted to other, nonsustainable uses is through systematic preservation of sample ecosystems in parks and protected areas. Another approach is to enhance the value of the forest by developing its resources other than timber—the nonwood products and forest food sources. For either approach to succeed, willing involvement of local people and political commitment from government decisionmakers are essential.

Maintaining Sample Ecosystems

Parks and protected areas can be managed for direct income (e.g., tourism) and for indirect benefits, such as preventing siltation of reservoirs. Some of these benefits can be estimated for resource allocation decisions. Other major benefits provided by protected areas-e. g., preservation of biological diversity-cannot be measured in dollars. Thus, in the past, the locations of protected areas have been determined more for watershed protection or tourist potential than consideration of biological diversity.

A marked disparity exists in the worldwide distribution of parks and protected areas, with some types of ecosystems well represented and others not represented at all. Many legally protected areas lack firm commitments from local, national, and international agencies. Consequently, they receive little actual protection or are inadequately managed. Strict preservation with total exclusion of economic activity is not practical for many sites where protection of undisturbed forests is important. Recognizing the growing demands to develop rural land, protected area planners and managers have begun to pay more attention to socioeconomic and institutional factors. They seek participation from both the people who will affect or be affected by forest resources and the people and agencies that must support management programs.

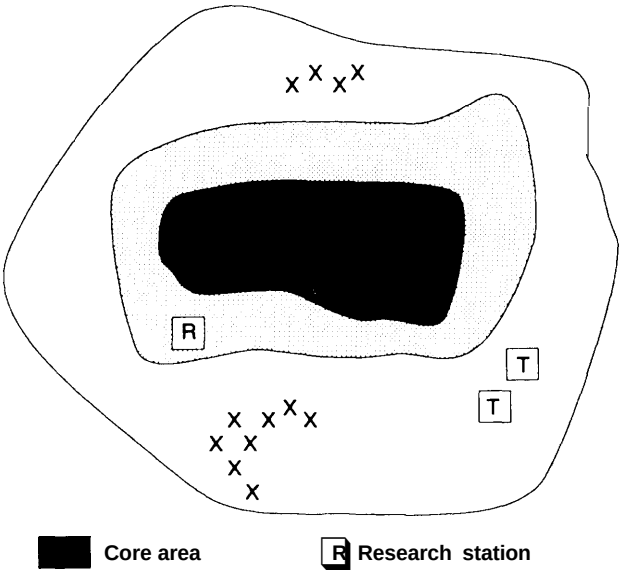
Some innovative plans that include the surrounding biophysical and socioeconomic setting have been developed for protected areas. One such activity is the UNESCO Man and the Biosphere (MAB) program's worldwide network of biosphere reserves (fig. 3). The management of these reserves considers the needs of local populations and seeks ways to make benefits available to local people. More field experience and monitoring are needed to evaluate the successes of existing biosphere reserves. However, the MAB effort is constrained by a lack of strong, consistent commitments from U.S. and other governments.

Making Undisturbed Forests More Valuable

Few deliberate attempts have been made to harvest forest products other than timber and fuelwood in a sustainable, organized way. Incentives to maintain unlogged forests would be greater if methods were developed to use forest resources other than timber more filly-either by discovering new, valuable products or by encouraging collection and processing of existing products.

Products obtained from animals and from wood, bark, leaves, or roots of trees and other forest

Figure 3—A Typical Biosphere Reserve



The biosphere reserve considers the needs of the local people by incorporating biophysical and socioeconomic factors into its management plan.

SOURCE: M. Batisse, "The Biosphere Reserve: A Tool for Environmental Conservation and Management," *EnvironmentalConservation*, vol. 9, summer 1982.

vegetation offer significant opportunities for tropical countries to develop cottage industries. Employment and incomes for people living in or near forests could be improved while encouraging maintenance of the natural ecosystems. Improved assessment of the role of forest products in subsistence economies and development of markets for nonwood products could help decisionmakers recognize the value of undisturbed forests. U.S. scientific and managerial expertise could be applied to this problem, especially from the fields of ecology, botany, business, and forest management. Few technologies exist today that can extract selected renewable resources from a tropical forest while leaving the forest nearly intact. Crocodile and butterfly farming are two examples that are being implemented. The development of other such resource-conserving systems is needed.

Technologies to Reduce Overcutting

Much resource degradation is caused in closed tropical forests by inappropriate wood harvesting methods and in mountain and dry forests by cutting more wood than grows each year. Development of improved wood processing technologies and markets for more of the many tree species and sizes growing in the closed forests would reduce the area that must be logged to satisfy timber demand. Where too much wood is being cut, it may be necessary to reduce demand by increasing the efficiency of woodstoves and charcoal kilns or by substituting alternative energy sources.

Industrial Wood

Intensive forest harvesting could give increased output per unit area, thus reducing demand to cut elsewhere. But this approach can have positive and negative impacts. It can make reforestation planting more feasible. On the other hand, it increases the potential for damage to the site from poor road engineering, inadequate site protection, and tardy restoration of forest stands. Intensive harvesting would require strict enforcement of regulations to prevent adverse impacts on the land's long-term productivity.

Intensive harvesting depends on the availability of profitable technologies to extract, process, and market a wider range of tree species and sizes. Grouping species according to their uses (e.g., construction material) is an approach that has been successful in Africa. However, many unused species have sizes, shapes, or wood characteristics that make



Photo credit: L. Lind, USDA Forest Service

Throughout much of South Asia and Africa, fodder for livestock is as important a forestry product as wood. Like logging, however, the potential for overcutting exists without controls on timing or amounts removed.

them difficult to harvest and process and that limit their usefulness.

The use of smaller trees would require costly replacement of existing equipment designed for large logs. Portable sawmills and small units that could be carried easily and set up to mill logs at the stump could make logging much more efficient. Such technologies might minimize adverse environmental effects from hauling logs but might encourage logging of currently inaccessible areas.

The greatest progress toward making intensive harvest profitable has occurred where multispecies wood chips are produced for wood pulp or fuel. The "press-dry paper process" developed at the U.S. Forest Products Laboratory promises to increase the world market for hardwood chips. However, chipping can have adverse impacts because in moist tropical forests most of the plant nutrients are located in the trees rather than in the soil. Thus, wood chip harvesting that removes most trees can severely reduce the fertility of the site.

For little known but potentially marketable lumber species, cost-effective preservation and drying technologies are needed to improve use characteristics. Many types of wood are susceptible to attack by termites, other insects, or fungi under tropical conditions. Although wood preservatives are available, they generally are costly. Some less expensive techniques exist, but their effectiveness has not been proven.

Fuelwood

Approximately 80 percent of the estimated 1 billion cubic meters of wood removed annually from tropical forests is used for fuel.[13] The effects of excessive fuelwood cutting are seen frost near cities and towns where fuel demand is concentrated. But overcutting does not always remain a local problem. Mangrove forests of Thailand and dry forests of Kenya, for example, are overcut to produce charcoal that is transported by ship to other nations.

Most wood fuel is used in homes for cooking, though tobacco drying and other rural industries also consume substantial quantities. Common domestic stoves waste much of the wood energy, as do traditional methods of making charcoal. Therefore,



Photo credit: S. Pandey, USDA Forest Service

With most tropical nations still dependent mainly on wood and crop residues for cookng fuel, enhancing fuel-use efficiency by introducing improved stoves is a major opportunity for technology development to reduce pressure on forests, especially in semi-arid areas.

it should be possible to reduce fuelwood demand and consequent overcutting significantly by disseminating more efficient stoves and charcoal kilns. Attempts to introduce such technologies in tropical nations have had mixed success. Improved stoves are not quickly and widely accepted. Though cheap by U.S. standards, they often cost too much. Some reduce the range of fuels that can be used. Further, improved charcoal production sometimes does not lead to less wood cutting because charcoal makers may use the time or profits they gain to make even more charcoal. Techniques to reduce demand require especially careful planning, monitoring, and evaluation.

Nonwood fuels such as kerosene can sometimes be used to reduce wood demand temporarily while fuelwood plantations are established and while natural forests recover fromn exploitation. But the costs of obtaining and distributing nonwood fuel substitutes are often prohibitive, especially to the rural poor. Small-scale, renewable energy technologies such as solar dryers have more potential for

13 In the decade from 1979 t. 1989, total wood removals from tropical country forests rose by about 25 percent. Estimated fuelwood consumption in tropical countries remains at about 80 percent of total wood use [United Nations, Food and Agriculture Organization ''Forest Products Yearbook: 1978-1989, " Rome, Italy, 1991].

long-term use, but their adoption is inhibited by financial and managerial constraints.

Substituting plantation-grown wood for natural forest wood clearly is an important option in many tropical regions. Investment in plantations is constrained, however, where access to "free-for-the-taking' forest wood is not restricted. Thus, regulatory controls on fuelwood gathering from the natural forest must be enforced if the fuelwood plantation option is to be used before all the accessible natural forests are destroyed. Where fuelwood has commercial value above the cost of cutting and transportation, the possibility exists that farmers and business will invest in planting trees.

Securing future wood supplies is a social, political, and economic problem. Investments of land, labor, and capital in tree growing are constrained by problems with land ownership, laws, and social organization. Until these are resolved and woodfuel supplies are being effectively replenished, measures to reduce demand will fail to reach the root of the problem. Demand reduction creates no incentives for increased supply; it may achieve the reverse.

Technologies for Disturbed Forests

An estimated 400 million hectares of potentially productive secondary forest[14] exist in closed tropical forest areas. Approximately 2 billion hectares of tropical lands are in various stages of degradation. Investment in the improvement of secondary forests and reforestation of degraded lands offers opportunities to meet needs for materials, substitute domestic production for imports, and provide new sources of employment in wood production and processing.

Management of Secondary Forests

Many tropical countries could sustain production of all the wood they will need for decades if adequate investments were made to develop and manage cutover secondary forests. However, such investments are seldom made. Land tenure can be a constraint, but even where the forests are clearly owned and controlled by government forestry agencies or private landowners, investments are usually inadequate. Technologies for sustained forest production exist, but for most of these the time lag before payback begins is too long and return on the investments is too low to attract adequate private and public capital. Opportunities to improve this situation include:

- resolution of land tenure issues,
- public and private investments in research and development to make sustainable secondary forest management more profitable,
- increased technology transfer of profitable resource-sustaining forest management methods, and
- implementation of resource use regulations, tax laws, or subsidies to make investments in secondary forest management more profitable.

Simply reducing logging damage by using appropriate or improved harvesting equipment can increase the number of trees available for a future crop, as well as increase natural regeneration and facilitate enrichment planting. But to ensure this occurs, regulations to control logging practices must be enforced.

Reforestation of Degraded Lands

Technologies are available to reforest certain degraded lands. But tree planting sometimes does not compete well, in economic terms, with other land uses. The solutions to this dilemma include reducing reforestation costs, reducing plantation failure rates by enlisting support of local people, increasing plantation yields, and developing methods to quantify the indirect benefits of reforestation.

Reforestation costs can be reduced if land preparation is used to reduce weed invasion and ensure a favorable environment for seedling growth. Plantation yields can be increased by selecting high-yielding, fast-growing, soil-enriching, and stress-tolerant tree species. Developing and implementing tree breeding and improvement programs can produce varieties with high yields and other desired characteristics. Careful provenance testing—matching the appropriate variety to a particular site—should improve species performance and reduce mortality.

To achieve successful reforestation, several constraints must be overcome:

. shortage of planting stock and lack of quality control in seed and clone production,

[14] Secondary forest includes both residual forest that has been cut once or several times during the past 60 to 80 years and second growth-forests that invade after periodic cultivation.

. inadequate knowledge of tropical site conditions, and
- lack of information dissemination.

The coordination of collection, certification, and international distribution of high-quality seeds in commercial quantities needs to be improved. Information on proven silvicultural techniques must be disseminated to the local people.

These technical problems can be solved, given adequate funding and time. A more subtle problem is to get local people to maintain tree plantations. First of all, they must clearly understand the reasons for planting trees. The trees should produce products local people want, and the people must be convinced that substantial benefits from the trees will accrue directly to them. Often this means using species selected by local people rather than species selected by foresters.



Photo credit: Walter E. Parham, Office of Technology Assessment

Substantial progress has been made in describing and developing agroforestry systems that combine woody and non-woody species on a single plot of land. Agroforestry systems commonly are developed based on traditional agroforestry models such as those practiced in southern China combining food, fuel, and medicine production.

Forestry Technologies to Support Tropical Agriculture

Medium-and long-term maintenance of tropical forest resources may depend more on sustaining the land already under cultivation than on refining use of the remaining forest. Introducing woody perennials into farming and pastoral land (agroforestry) and improving farming techniques for upland watershed areas could help sustain the productivity of lands under cultivation and so reduce the need to clear additional forest lands.

Agroforestry

Agroforestry encompasses many well-known and long-practiced land-use methods. The aim is to create productive farming systems able to supply a higher and more sustainable output of basic needs and saleable products than occurs without trees. Agroforestry is most important on lands with serious soil fertility problems and lands where inadequate rural infrastructure makes it vital for people to produce most of their own basic needs for fertilizers, food, fodder, fuel, and shelter.

Agroforestry is a newly recognized field and could benefit from a critical examination of practices and quantification of information. Since agroforestry cuts across several disciplines, its research and development requires an interdisciplinary approach. Because of fragmented institutional jurisdiction, however, agroforestry is not receiving adequate support from either forestry or agricultural institutions.[15]

Great technological potential for agroforestry seems to lie in genetic improvement (systematic breeding and selection) of multipurpose tree and shrub species. Selection of appropriate provenances, subspecies, and varieties can greatly enhance the success of agricultural systems designed for particular land requirements.

The potential for farmers and pastoralists to adopt agroforestry system improvements is more difficult to assess. Peasant farmers can ill afford the risks of innovation. Large-scale adoption of new agroforestry systems would require creating incentives to enable people to implement new practices in spite of the initial risks and delayed returns.

15 Several research organizations located in tropical nations carried out important research on agroforestry during the 1980s. In 1991, forestry, agroforestry, and related environmental issues were incorporated in the mandate of the Consultative Group for International Agricultural Research (CGIAR), the major network of research institutions funded by bilateral and multilateral donors to support development in tropical regions. (See introduction.)

Watershed Management

The greatest problems in tropical watersheds occur where subsistence farmers and their livestock move onto steep uplands. Excluding farmers and livestock from such areas can allow vegetation **time to** recover, but enforcing such policies is difficult. Mechanical structures and replanting methods can restore water flow stability from some deforested slopes. Further, conservation practices exist that allow farming and grazing on many moderate watershed slopes. However, the watershed management techniques are unlikely to become widespread until farmers and herders in upland areas have incentives to stop destructive land-use practices. To provide upland farmers with nondestructive land-use alternatives necessitates:

- developing methods of land use that are more profitable to the local community and at the same time improve control of water flows;
- developing improved techniques to measure and predict tradeoffs of different management actions; and
- testing new technologies and getting the useful ones adopted by the local community. Subsidies from downstream beneficiaries of the watershed protection may be necessary. Sociological studies could help define the type of incentives needed to obtain farmers' cooperation.

Resource Development Planning

Most conversions of tropical forests to other land uses take place without adequate consideration of whether the natural and human resources available can sustain the new land use. Sometimes, destructive forest conversions are an unplanned result of some other, narrowly planned development. For instance, poorly sited logging roads can open highly erodible forest land to unplanned clearing for slash-and-bum agriculture.

This problem can be ameliorated through the use of resource development plarming techniques that match land development activities to the natural and human capabilities of specific sites. These techniques can identify which sites can sustain crop production, grazing, reservoirs, new settlements, intensive forestry or agroforestry, and which will be most productive if retained as natural forest.

Ideally, resource development planning includes four components: biophysical assessment, financial (investor's viewpoint) and economic (society's viewpoint) assessment, social assessment, and project monitoring and evaluation. Biophysical assessment is used more often than the others, although it still is underused. Furthermore, the techniques commonly are used to determine the best sites for particular development purposes rather than to develop a comprehensive strategy for all sites in a region.

Use of each of the four planning components is constrained by a lack of information on cause-and-effect relationships. Economic assessment encounters difficulty measuring nonrnarket values. Farther, the analyses may consider the forest values only of a small site, disregarding the interrelationships between that site and the surrounding area. For example, loss of the genetic resources in a small patch of a large forest may seem unimportant because nearby forested areas contain the same biological diversity. Consequently, individual economic analyses may justify clearing the forested region piece by piece without accounting for the overall genetic loss incurred.

Finally, even well-planned development may prove unsustainable if planning stops after implementation begins. Most planning is done before projects begin, when least is known about biophysical and human resources at the site. Continuous planning, monitoring, and evaluation are necessary during and after the project. The major development assistance organizations have begun to institute such procedures but have not yet determined how to use the results.

Opportunities to enhance the use of resource development planning include improving data availability, more demonstration of the techniques' potentials, better communication of planning success, increasing the number of trained planners, improving techniques for economic and social analysis, and assuring that projects remain open to redirection after implementation begins.

Education, Research, and Technology Transfer

Forest resource development is constrained in most tropical nations by a shortage of professional and technical personnel who know about appropriate technologies and who also understand the institutional, economic, and cultural aspects of forest

resource systems. In the near term, expatriates, including U.S. professionals, can provide some expertise. But this is not likely to be sufficient because the scope of tropical forest resource problems is so large and the number of expatriate experts is small. Further, expatriates lack the political and cultural ties necessary to influence policy. Sustaining tropical forest resources requires development of indigenous expertise in all aspects of resource development. Education, research, and technology transfer are the means to develop expertise both in the United States and in tropical nations.

Education

U.S. universities can act to sustain tropical forests in two ways: educating professionals who will work in tropical forestry-related fields and strengthening tropical nations' universities. However, tropical forestry is peripheral to the interests of most U.S. forestry schools and the experts are scattered widely among institutions. Consequently, efficient mechanisms must be developed to bring together multidisciplinary teams of researchers and educators and connect them with students, foreign universities, and other seeking to develop tropical forest expertise.[16]

Twinning, which creates associations between tropical nation institutions and individual developed nation institutions, has worked with a few university forestry schools. Consortia of U.S. universities can provide tropical institutions access to a wider range of expertise and experience than twinning arrangements. However, this approach still does not resolve several of the fundamental deficiencies that reduce the effectiveness of U.S. institutions. U.S. forestry schools lack tropical settings for teaching and research. Further, their curricula do not prepare students to solve the social and institutional problems that confront tropical forest resource development. The development of one or more U.S. centers of excellence in tropical forestry might resolve these deficiencies. For example, a center of excellence in Puerto Rico could focus on Latin American forest development needs, providing the necessary tropical setting as well as benefiting the U.S. tropical forests.

A major objective of U.S. efforts to enhance tropical forest education could be to strengthen schools in the Tropics. Some 138 **universities** and 220 **technical** schools in tropical nations provide forestry education and training. Nearly all these schools are new. Most are small and produce few graduates each year. Thus, substantial support is needed to provide in-service faculty training, to produce locally relevant course materials, and to modernize basic education facilities such as herbarium, library collections, and computers.

Resource development professionals, the scientists who develop technologies and the technicians who implement them, are ineffective without strong support from the many people who make decisions about the use of natural resources. Environmental education aims to change people's attitudes and behavior by providing them with the motivation and the knowledge necessary to make decisions and take actions that will sustain natural resource productivity.

Environmental education efforts can be directed **at the** general public using mass media or programs in primary and secondary schools. Or the efforts can be directed more narrowly at higher level decisionmakers. Unfortunately, the behavioral science basis for environmental education is not well established, so the techniques must be developed by unscientific trial and error. This development could be accelerated if significant investments were made to evaluate, document, and communicate the environmental education efforts that are under way. Having neither a strong scientific foundation nor substantial documentation of the causes of program success and failure, environmental education projects have a difficult time competing with other projects for funds and personnel.

Research

Technologies intended **to** develop renewable resources are likely to fail if they are based o n inadequate knowledge. Thus, both fundamental and applied research are necessary components of any strategy to sustain tropical forest resources. Fundamental research is the foundation for applied research, while applied research is needed to improve existing forestry technologies and develop new technologies.

16 Substantial networking among academicians interested in tropical forestry occurred during the past decade. The U.S. Forest Service, AID, non-governm ent organizations working in tropical forestry, university consortia organized for international development assistance, and private consulting firms have established databases to facilitate matching U.S. forestry academicians to developing country needs and opportunities for training, research, and technical assistance.

Many experts conclude that sustaining tropical forests is not so much a technical problem as it is an institutional problem. Thus, research is especially needed to determine the interactions between the social and biophysical factors of tropical forest systems. Some knowledge about social and institutional factors is being used in resource development projects supported by U.S. agencies. However, this knowledge usually is based on personal experience, not on careful research. A substantial increase in truly interdisciplinary research could enhance the likelihood that institutional changes would result in sustainable forest resource development.

The techniques used to manage tropical forest resources are generally based on trial-and-error experience gained in past centuries. They have benefited little from the rapid advances in fundamental and applied biology that have occurred recently. **For most tropical forest types, techniques** have not been developed that can:

- produce the products, environmental services, and employment opportunities that local people need, *and*
- sustain the productivity of the resource base, *and*
- be profitable enough to motivate people to risk their scarce capital, labor, and land.

Applied research to improve existing technologies probably will not suffice to meet these goals. Innovations based on new fundamental research will also be necessary.

Low levels and short periods of funding are major constraints on fundamental research in tropical areas, but these are not the only reasons why basic knowledge is inadequate to sustain tropical forests. Most fundamental research in tropical biology has been designed to develop evolutionary theory, and relatively little work has been done or is being done on ecological theory.

Another problem is poor communication among researchers and between researchers and technology users. Most forestry and biology research organizations reward scientists, including those working on applied research, for publishing in journals that technology users seldom read. In fact, few journals exist that are designed to communicate research results to resource developers. The U.S. Forest Service periodical *The Caribbean Forester* once served this purpose but has been discontinued. As a result of poor communication, the pace of innovation is slower than it needs to be, techniques are reinvented, some mistakes are continually repeated, and potentially successful technologies spread slowly, if at all.

Technology Transfer

The experience of U.S. forestry organizations shows that many potentially profitable techniques languish for lack of effective technology transfer among scientists, between scientists and technology users, and among technology users. Thus, it is appropriate that international development assistance organizations focus their efforts not on promoting particular technologies but rather on building local institutions' capacities to choose, receive, adapt, and deliver technologies appropriate to local circumstances.

An important constraint on development assistance effectiveness in forestry is the lack of coordination among many bilateral and multilateral projects. Coordination of resource development projects so that each project contributes the appropriate actions at the appropriate time to accomplish long-range plans should be the responsibility of tropical governments. But donor agencies usually fund the projects they identify rather than projects identified in some long-term planning process. One approach to improve planning and coordination of technology transfer is the use of ad hoc international committees that are separate from the policies and problems of individual government agencies or development assistance organizations.[17] Committees such as the newly instituted Coordination for Development in Africa could assist tropical governments in developing long-range plans and in identifying and recommending projects for the various international organizations.

The OTA assessment identified a number of necessary conditions for successful technology transfer.[18] For most technologies, the lack of these

17 Important progress in development assistance planning and coordination for forestry has occurred since 1985. The Tropical Forestry Action Plan process, facilitated by FAO, and the Forestry Master Plans being facilitated by the multilateral development banks, are identifying forestry development priorities and providing a framework for focusing and coordinating the efforts of donor agencies. (See introduction.)

18 These conditions were a result of discussions among OTA staff; Roger Moeller, AID; and Gary Eilerts, Appropriate Technology International.

conditions seems to be constraining wider adaptation and adoption:

- Technology is transferred most effectively by direct people-to-people actions. People who are to adapt and apply the technology need to learn it directly from people who have experience applying it.
- Technology needs to be adapted at the users' end to local biophysical and socioeconomic conditions.
- Well-qualified people with knowledge about the technology are needed on the source end of the transfer, and receptive, capable people are needed on the receiving end. These people may be local transfer agents or they maybe the end users.
- Another type of actor, the ' 'facilitator," is also necessary. Facilitators understand the technology transfer process, including the market for the technology and its products and the political, social, and economic constraints and opportunities that affect all the other actors.
- Users and transfer agents should be involved in choosing the technologies and in planning and implementing the transfer process so the technology and the transfer meet actual needs and are appropriate for the local situation.
- All parties involved-source, transfer agents, facilitators, and end users—must feel they are winners and must, in fact, be winners. Each actor's self-interests should be identified at the start of the technology transfer process so they can be addressed.
- Each participant must be aware of subsequent steps in the transfer process so his or her actions are appropriate to the later steps. This requires early definition of roles for each person involved.
- The environment for technology demonstrations should be similar to the environment that will exist during subsequent steps of the transfer process. Pilot transfer projects should not be unrealistically easy.
- The initial commitment of resources to the process should be sufficient to carry the technology transfer until it is self-supporting.
- The transfer process must include mechanisms through which all participants can contribute effectively to interim evaluations and improvements.

ISSUES AND OPTIONS FOR CONGRESS

Tropical forest resources represent a great opportunity for sustained development because they are fundamentally renewable. However, too little such development is occurring. Instead, the productivity of the forests continues to be diminished. The U.S. Congress has already helped to sustain tropical forests by directing AID and the U.S. representatives to international organizations to give forest resource development higher priority in development assistance programs. To expand this progress, Congress could take actions that would enhance tropical governments' abilities to plan and coordinate resource development projects.[19]

The underlying causes of forest resource deterioration are institutional, social, and economic. Consequently, the reforms needed to support sustainable resource development can only come from the governments and people of the tropical nations. However, the United States can help stimulate such reforms. Some U.S. technologies, such as Landsat imagery, already supply vital information to improve resource development decisions. U.S. diplomacy—for example, supporting the United Nations Environment Programme and UNESCO'S Man and the Biosphere program-also can help to foster understanding of resource problems and coordinate international efforts to resolve them.

Congress can address technical constraints more directly. U.S. and international organizations that Congress can influence have the capability to: 1) develop production systems that provide the basic needs of local people while conserving forest productivity, and 2) assist tropical organizations and individuals in developing, adapting, and implementing such technologies. U.S. agencies that are applying this type of expertise include AID, the Forest Service, the National Academy of Sciences, the National Park Service, the Fish and Wildlife Service, and the Soil Conservation Service. Some commercial fins, private voluntary organizations,

[19] The impact of these congressional directives, and continuing attention from Congress, has been substantial. AID's investment in forestry projects rose to about $130 million per year by 1991. Comparable investment in agricultural activities is $565 million. Multilateral development banks have also increased investments in tropical forestry. (See introduction.)



Photo credit: Walter E. Parham, Office of Technology Assessment

Coordination of international development organizations' assistance in developing, adapting, and implementing agriculture and forestry systems could eliminate duplication and inconsistency and improve cost-effectiveness of interventions, necessary objectives in regions with widespread and severe land degradation such **as Haiti's once-forested hillsides.**

and U.S. universities also have expertise relevant to sustaining tropical forest resources.

Congress has ways to influence multilateral banks and U.N. agencies, some obvious (e.g., through allocation of funds and assistance) and some subtle (e.g., using the prestige of Congress to give credibility to a new idea), The final chapter describes opportunities for congressional action to:

- expand and coordinate development assistance,
- encourage resource development planning,
- improve tropical forest research and development efforts,
- protect biological diversity, and
- expand U.S. expertise in tropical forest resources.

U.S. tropical forests are discussed separately in this summary.

Expand and Coordinate Development Assistance

issue (Projects): Development assistance progress is slow and the gains are insufficient to sustain tropical forest resources. Many opportunities exist to enhance gains already made, but congressional vigilance is necessary to ensure that forestry projects receive an appropriate share of U.S. development assistance funds and that other types of projects complement the forestry efforts.

The Foreign Assistance Act directs development assistance organizations in which the United States participates to give higher priority to protecting against the loss and degradation of tropical forests. Accordingly, AID, the World Bank, the U.N. Food and Agriculture Organization (FAO), and some other multilateral organizations have increased funding in recent years for forest-related projects. However, many opportunities for use of development assistance to sustain tropical forest resources are not being pursued adequately. Examples of such opportunities are:

- emphasize agroforestry and innovative crops and techniques that can sustain permanent agriculture on relatively poor soils;
- promote reforestation and management of natural forests to sustain environmental services and produce fuelwood, construction wood, polewood, and nonwood products;
- stress institution-building to enable tropical governments to exercise improved control over timber concession operators; and
- support livestock projects that do not result in deforestation or forest degradation.

Option—To encourage expanded support for forestry projects, committees of Congress could continue oversight hearings requesting AID officials and U.S representatives to multilateral development assistance organizations to testify on the extent to which assistance practices accomplish the objectives set forth in Section 118 of the Foreign Assistance Act.

Issue (Coordination): Development assistance agencies generally do not coordinate their projects effectively at the country or regional level. To improve their effectiveness, projects could be organized as steps in comprehensive strategies designed to develop sustainable forest resource use systems. Individual development assistance agencies have neither developed nor coordinated such strategies.[20]

[20] Coordination of forestry sector development assistance funding is an expressed goal of the Tropical Forestry Action Plan. (See Introduction.)

The reasons why host governments and international assistance organizations do not coordinate activities more effectively are complex. But coordination could play a key role in improving the cost effectiveness of U.S. assistance. If the Congress decides that improving cost effectiveness is worth relinquishing some degree of U.S. control over what projects are funded, it could mandate increased U.S. effort to enhance the tropical nations' abilities to coordinate the work of development assistance organizations.

Options-One way to begin such a fundamental shift in the development assistance process would be to direct the Department of State to assess whether various tropical nations are able and politically ready to develop long-term action plans for sustained forest resource development. Another mechanism is to create ad hoc committees of experts from donor nations and tropical nations to work together to identify problems and plan regional forest resource development strategies.

Encourage Resource Development Planning

Issue: Although resource development planning technologies can improve the sustainability of tropical forest development, they are seldom applied to their full potential.

Resource development planning techniques can be used to identify development activities that match the available human and natural resources. The techniques can give decisionmakers a clearer picture of the social, economic, and environmental implications of a particular type of development on a particular site. Also, they can be used to determine the best locations for protection of natural areas to maintain biological diversity while providing tangible benefits. But the application of planning is hampered by shortages of information on how biophysical, social, and economic factors interact.

Options-To encourage the use of resource development planning, Congress could maintain the availability of low-cost Landsat images to tropical governments. Congress also could direct AID to expand its Environmental Profiles to include macro-level land classification and collection of information for social and institutional analyses. Further, Congress could direct U.S. representatives to multilateral development banks to promote environmental assessments at an early stage of project planning. This request could be followed up with hearings to determine whether the banks are using environmental assessment procedures effectively.

Improve Tropical Forest Research and Market Development

Issue (Research): Fundamental research, applied research, and technology implementation related to tropical forests are not well coordinated. Moreover, interactions among factors that constrain forest resource development are poorly understood. Consequently, resource development projects often fail and technologies that seem to succeed in trials fail to spread beyond demonstration areas. Research on tropical forest resources needs to be more interdisciplinary and more closely related to technology implementation.

Much work remains to develop profitable technologies that can supply local people's needs while simultaneously sustaining forest productivity. New techniques need to be based on improved understanding of the biological, economic, and cultural factors affecting forest resources. This calls for interdisciplinary research based on an adequate understanding of the needs of technology implementors.

Options-Initially, Congress could conduct hearings to determine whether the research organizations that receive U.S. funds give adequate priority to interdisciplinary tropical forestry that links research and development. Special attention should be paid to disseminating research results. Congress could increase support for agencies where such research and development is stressed.

The other approaches would be for Congress to appropriate funds specifically to support UNESCO's MAB program or to amend the Foreign Assistance Act to include funds for the United Nations University. Both promote interdisciplinary research. Additionally, Congress could amend the existing legislation that explicitly allocates funds for tropical agriculture to include tropical forestry, and Congress also could determine the feasibility of establishing a forestry research program at existing Consultative Group on International Agricultural Research (CGIAR) institutions.[21] Congress could establish a trust fund for the Forestry Department of FAO

21 The CGIAR has added fores&y and agroforestry to its mandate. (See Introduction.)

specifically to support improved communication among researchers and technology implementors.

Issue (Market Development): In many areas, Sustaning tropical forest resources will depend on markets for local forest products. People seldom attempt to sustain the productivity of natural resources used for subsistence products because these appear to be "free.' Government agencies typically are not aware of the natural forest potential to support rural communities.

Tropical forest ecosystems house complex associations of vegetation, wildlife, and other potential resources that could be developed. Development of markets, along with research on ways to manage the unused resources for sustained yields, could help motivate local people and local resource agencies to manage the forests effectively. It could be possible in some places to maintain biological diversity and simultaneously support profitable rural development. However, such market development is likely to reduce economic and even subsistence opportunities for landless poor people.

Options-Congress could direct and fund the U.S. Forest Products Laboratory to develop new products and market information to use tropical tree species and increase its efforts to transfer technologies. Similarly, AID could be directed to expand its support for synthesis and dissemination of information on underused tropical forest resources and to begin developing markets for those products that can be produced on a sustainable basis.

Protect Biological Diversity

Issue: Benefits from preserving the biological diversity of tropical forests accrue to society as a whole, including future generations in the United States and elsewhere, yet the costs are borne by the people of tropical countries.

Developing new markets and ways of harvesting and using tropical forest species eventually may make it possible to manage natural forests profitably and sustainably. But until the markets and technologies are developed, it is necessary to protect and maintain undisturbed portions of these biologically diverse ecosystems for future generations.

Options-Congress could take two approaches to help maintain biological diversity. First, it could conduct hearings on its recent amendment to the Foreign Assistance Act which directs AID, in concert with other appropriate agencies, to develop a comprehensive U.S. strategy to maintain biological diversity.

Additionally, Congress could support the creation of an international fund to subsidize the establishment and maintenance of tropical parks and protected areas. Money for such a fund could be contributed by a variety of sources, including transfers from existing assistance agencies (e.g., AID, multilateral development banks, and U.N. agencies), increased export taxes and import duties *on* tropical forest products, and donations from private foundations and multinational corporations.[22]

Expand U.S. Expertise in Tropical Forest Resources

Issue: U.S. tropical forest resource expertise is widely scattered and is not being developed or used effectively .23

The United States has recognized expertise (both individuals and organizations) in many resource fields, including reforestation, watershed management, commercial forestry, resource inventory and mapping, resource development planning, and information collection, processing, and dissemination. But only a few of these experts or organizations have the experience or training to apply their skills

22 The Global Environment Facility (GEF), organized under the United Nations Development Programme, Environment Programme, and the World Bank, planned approval for 15 projects in 1991 with a combined cost of $215 million. This is the first tranche in the three-year pilot program of GEF. Of the first 26 projects planned, 11 (mainly biodiversity projects) were focused on tropical forests [United Nations Development Programme, "Global Environment Facility Work Program: Fiscal Year 1992 - First Tranche'' (Washington DC: World Bank, 1991)].

23 Increased AID funding for tropical forestry has resulted in substantial improvement in the use of American expertise and the transfer Of American technical knowledge. For example, a new Office of International Forestry, authorized by the 1990 International Forestry Cooperation Act (Title VI of the Foreign Operations Appropriations Act), has been established to coordinate expansion of educational and training assistance in forest management, cooperative research, direct forest management assistance, and protection of forest resources. In 1983, some 3.6 million hectares of tropical forest were destroyed by wildfires in Indonesia. Apparently wildfires of this scale are a new threat to tropical forests, caused by human-caused changes in the forest conditions during droughts [D. Poore, et al., No Timber Without Trees: Sustainability in the Tropical Forest (London, England: Earthscan, 1989)1. Indonesia's 1991 fiie season seems likely to result in extraordinary damage again. Responding within a few days to a request from the Indonesian government, the U.S. Forest Service dispatched a team of fire prevention and control experts to assess the problem and to develop recommendations, possibly including further U.S. assistance.

directly to the increasingly important field of tropical forest resources.

Options-Congress could modify the organic legislation of those U.S. agencies whose actions affect the tropical nations or the U.S. tropical territories to state that tropical forests are valuable renewable resources and to direct each agency to conduct its activities without contributing to the unplanned or unmanaged conversion or degradation of tropical forests. Further, Congress could direct Federal agencies to encourage employees to participate in international assistance efforts under existing laws or it could amend legislation to encourage such interchange. Congress could encourage participation of the U.S. private sector to develop and implement technologies to sustain tropical forest resources. Congress could contribute to the United Nations Associate Experts Program whereby young U.S. professionals can gain field experience in tropical forestry. Congress also could designate U.S. centers of excellence in tropical forest resources to develop and make available U.S. expertise in tropical resource issues.

U.S. TROPICAL FORESTS[24]

Introduction

Less than 1 percent of the world's tropical forests fall under U.S. jurisdiction. These forests are located primarily in Puerto Rico, the U.S. Virgin Islands, Hawaii, and the U.S. western Pacific territories of American Samoa and Micronesia (which includes Guam, the Commonwealth of the Northern Mariana Islands, and the Trust Territory of the Pacific Islands[25]). As Congress becomes more involved in efforts to sustain tropical forest resources worldwide, it has reason to pay particular attention to the tropical forests under its care.

Despite their small total land area, the U.S. tropical forests are important resources to local people and economies: they supply food, fodder, fuel, and employment; reduce erosion; and protect ocean fisheries. Most wood products, however, are imported to these areas. For example, Puerto Rico imported $400 million worth of wood products in 1981. Perhaps the most important value of forests on these tropical islands is regulation of water regimes. For instance, because of deforestation the U.S. Virgin Islands no longer has permanent streams. Most other islands also have experienced problems with water quality and quantity.

Only in Hawaii has forestry been made an integral part of the region's economic development.[26] To protect watershed values, most forested land in Hawaii is classified under conservation zoning which restricts or prohibits conversion to land uses other than forest. Nearly half of Hawaii's designated "commercial forest land" is owned by the State. Since 1962, the Hawaii Department of Land and Natural Resources has followed multiple-use programs for managing water, timber, livestock forage, recreation, and wildlife habitat on these lands. In addition, two of the three programs of the U.S. Forest Service Institute of Pacific Islands Forestry are dedicated to research on Hawaiian forests.

Even though forestry problems still exist in the Hawaiian islands (e.g., the recent dieback of native forests, endangerment of native plants and animals) considerable effort has been applied to understand and mitigate these problems. Numerous organizations working to sustain tropical forest resources are based in Hawaii, including the Nitrogen-Fixing Tree Association, the Bioenergy Development Corp., the East West Center, and the College of Tropical Agriculture and Human Resources at the University of Hawaii. These are among the sources of expertise

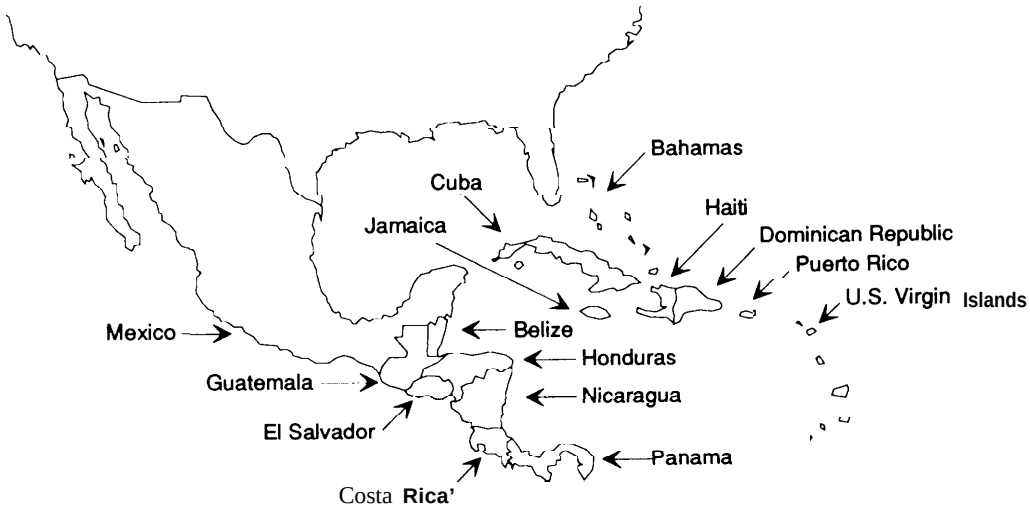
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24 Mom detailed analysis of U. S.-affiliated island forestry and agroforestry (and other natural resource management) technologies, issues and options is available in: U.S. Congress, Office of Technology Assessment *Integrated Renewable Resource Management for U.S. Insular Areas, OTA-F-325* (Springfield, VA: National Technical Information Service, June 1987.)

25 The Federated States of Micronesia and the Republic of the Marshall Islands, which (along with the Commonwealth of the Northern Mariana Islands and Palau) comprised the former Trust Territory of the United States, have signed Compacts of Free Association with United States to become Freely Associated States. This status allows the islands free control of internal affairs, assures them fiscal aid, and makes them eligible for some international aid; the United States retains responsibility for national defense [U.S. Congress, Office of Technology Assessment, *Integrated Renewable Resource Management for U.S. Insular Areas,* OTA-F-325 (Springfield, VA: National Technical Information Service, June 1987)]. Compact of Free Association negotiations with Palau are ongoing.

26 Since acquisition of portable sawmills in 1982, the Puerto Rican Forest Service has successfully and economically thinned, milled, and marketed teak, mahogany, and Caribbean pine from its Commonwealth forests; forest management and development of a wood products industry has subsequently resurged in local importance [D.J. Pool, "Forestry and Agroforestry Technologies: Development Potentials in U.S.-Affiliated Caribbean Islands," contractor report prepared the Office of Technology Assessment, *Integrated Renewable Resource Management for U.S. Insular Areas,* OTA-F-325 (Springfield VA: National Technical Information Service, June 1987)].

Figure 4—Location of Puerto Rico and the U.S. Virgin Islands



SOURCE: Office of Technology Assessment.

housed in Hawaii that can be applied to the U.S. tropical territories and to the world's tropical forest resources.

Forest resources in the U.S. Caribbean and Pacific tropical territories are not receiving a similar level of attention. The forests have suffered degradation in the past as a result of poor land use practices. More recently, incentives for local people to undertake and improve agricultural or forestry activities have been reduced by dependence on U.S. Federal income supports and by economic development focusing on industrial growth. This has resulted in a movement away from agriculture and a corresponding increase in abandoned agricultural land and unmanaged secondary forests. In many places, runoff and erosion resulting from past forest loss threaten water supplies and coastal marine resources. With forest resource development technologies, much of the productivity of this degraded and abandoned land could be restored to support economic growth.

Although current overexploitation of forest resources is not a problem in most of the territories, the remaining forests are vulnerable as populations and expectations rise. Future problems could be averted, however, if sustainable forest use techniques could be integrated into strategies for regional economic development.

The U.S. Caribbean Territories: Puerto Rico and the U.S. Virgin Islands

The Commonwealth of Puerto Rico is the largest contiguous tropical area under U.S. jurisdiction (see fig. 4). At least one-third of its land area is under forest cover—mostly second-growth trees, fruit tree plantations, and shade trees in coffee-growing regions. Because Puerto Rico has a relatively large forest area, a relatively well-developed road system, and secure land tenure, it has significant potential for commercial forestry to supply its domestic economy. About 200,000 acres in Puerto Rico have been identified as suitable for commercial forestry. However, large-scale forestry is hindered by high land prices and a law limiting the acreage that can be owned by an individual or corporation.

Opportunities exist to develop small-scale forest industries to serve domestic markets using technologies that require comparatively low capital outlay, such as the portable sawmills now used in Puerto Rican Commonwealth forests. The sawmills are one component of a Puerto Rico Department of Natural Resources program to bring private landholders into commercial forestry. This program relies heavily on U.S. Federal cost-sharing programs and on funding from the U.S. Forest Service's State and Private Forestry grants. Increased support for these activities could encourage plantation forestry and increase Puerto Rican self-sufficiency in forest products.

The U.S. Virgin Islands have little remaining forest and no forest industry but are used extensively for tourism. Lack of forest management and a growing population in the U.S. Virgin Islands have disturbed local water regimes. Thus, water must be shipped from Puerto Rico or desalinized from sea water at great expense. Reforestation and management of island watersheds could reduce runoff rates, decrease erosion, and enhance aquifer recharge.

The main constraints to sustaining tropical forest resources in the U.S. Caribbean are lack of support for existing forest resource development institutions and lack of a skilled cadre of local resource managers. The U.S. Forest Service maintains a forestry research station, the Institute of Tropical Forestry (ITF). It also manages the Caribbean National Forest and supports a State and Private Forestry cooperative program with the Puerto Rico Department of Natural Resources and the Virgin Islands Department of Agriculture. At a time when U.S. Forest Service research needs to be expanded to include agroforestry, watershed protection, and other areas of importance to landholders and the public, its research funds and staff size have been reduced.

In the short term, people with general tropical forestry expertise can be attracted to work in the U.S. Caribbean, but in the long term an established method to train people to manage natural resources specific to that region is needed. Increased environmental education, scholarships, and creation of a natural resource management curriculum at the University of Puerto Rico could help train the necessary resource managers. In the meantime, adequate Federal support of Puerto Rico and U.S. Virgin Islands forestry programs through the State Forestry Grants of the State and Private Forestry Division of the U.S. Forest Service are needed to stimulate development, demonstration, and coordination of desirable forestry practices.



Photo credit: USDA Forest Service

Artificial nests are **one component of the species recovery program for endangered Puerto Rican parrots in the Caribbean National Forest, the only tropical U.S. national forest.**

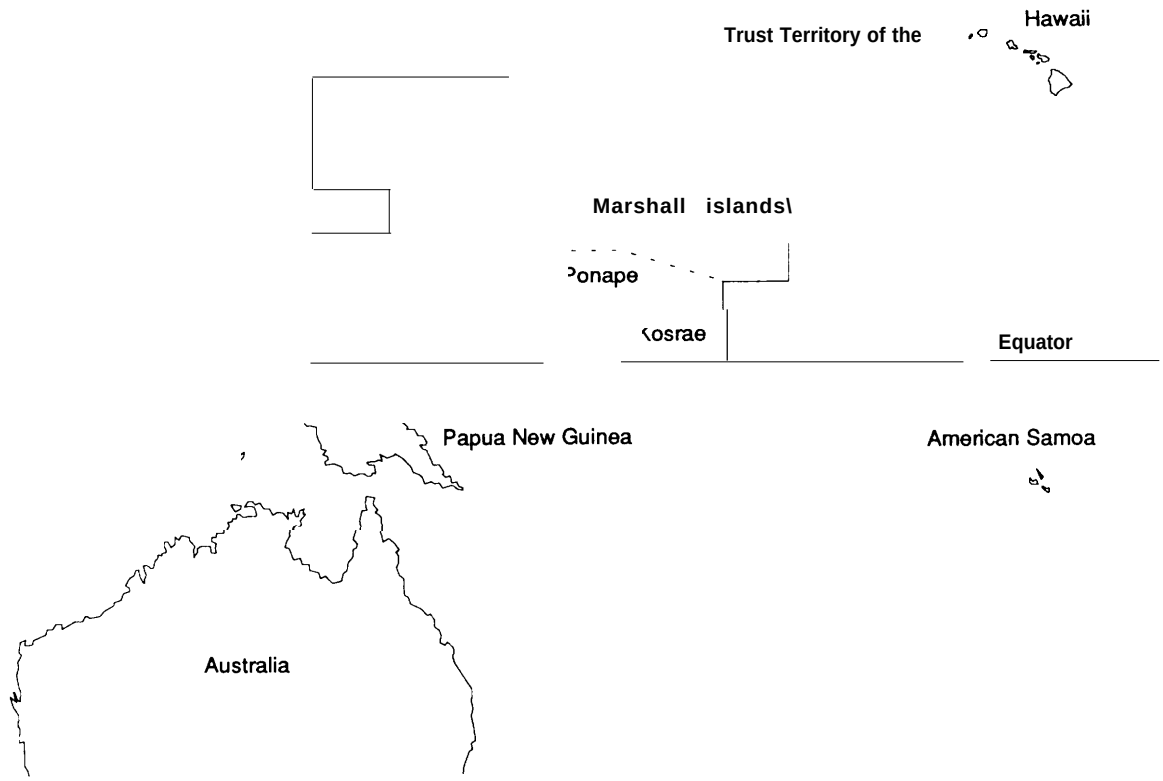
The U.S. Western Pacific: Micronesia and American Samoa

U.S. tropical forests exist on some 2,000 islands spread over 3 million square miles in the western Pacific (see fig. 5). Forest cover varies with the nature of each island. Few truly undisturbed forests exist, but considerable areas of secondary forest have regenerated. Little of this is managed to provide forest products. Fuelwood and some nonwood forest products are harvested for local use, but most wood products are imported.

As in the U.S. Caribbean, the major value of forest resources in the U.S. western Pacific is not timber but regulation of water regimes and protection of biologically rich coastal ecosystems. Island people in this region depend heavily for both subsistence and trade on marine organisms that feed and spawn in mangrove habitats, lagoons, and coral reefs. Unplanned exploitation of upland forests can substantially reduce the productivity of these coastal areas. This already is occurring on some islands.

Transportation costs, limited land areas, and insecure or communal land tenure limit the region's industrial forestry opportunities. However, small-scale management, harvesting, and processing technologies could be applied to the secondary forests and abandoned coconut plantations to increase their provision of food, fuel, employment, and other goods. For example, improved small-scale charcoal production, if developed and promoted wisely, could increase the importance of wood as a sustainable energy source in the U.S. Pacific. Production from existing agroforestry lands could be enhanced with new techniques. Coconut shell charcoal can be used as a falter in various industrial and pharmaceutical uses and could be exported from these islands.

Figure 5-Location of the U.S. Pacific Territories



SOURCE: Office of Technology Assessment.

Any forest development in the U.S. western Pacific territories, however, will require careful planning and management to avoid further degradation of the resources and to ensure the sustainable production of both goods and services provided by the forests. This requires up-to-date and comprehensive databases on tropical forest resources, their uses, and the potentials for their development. U.S. Federal agencies can play a major role in creating these databases.

Integrating forestry into development planning in the U.S. western Pacific will require personnel with substantial knowledge in tropical resource management and strong local institutions through which they can work. Yet, no natural resource management education and training programs exist in the U.S. western Pacific territories, and few of the students who receive training at U.S. or other institutions return to work in their own regions. Actions to help supply needed expertise include creating a natural resource management curriculum at the University of Guam and increasing scholarships for potential resource managers. Additional extension services also could be useful Developing a group of local grassroots naturalists with generalized training to assist scientists, spread information on appropriate land uses, and help integrate new technologies with local customs could be a joint undertaking of U.S. and local western Pacific organizations.

Issues and Options for Congress

The primary requirement for sustaining tropical forest resources in the U.S. tropical territories is the development of indigenous organizations capable of managing the islands' resources. Because the territories' governments still depend on U.S. support and their natural resource agencies are generally new, small, and undersupported, the U.S. retains a substantial role in both the development of the resource organizations and in the development and implementation of forest-sustaining technologies.

Option: Congress could direct the **U.S. Forest Service to expand the scope of research and technology development in its research institutions with jurisdiction in the U.S. tropical**

territories and increase cooperative efforts with local governments.[27]

Development of forestry management plans, in the short run, will require technical assistance provided by U.S. expertise. Similarly, adaptation of technologies to conditions in the U.S. tropical territories requires Federal assistance. In the long run Federal aid could be replaced when more people are trained in natural resource management at local institutions. Development of programs to encourage private forestry appropriate for each island probably also will require Federal assistance. The Federal organizations responsible for assisting forestry development in the U.S. tropical territories are too small and their focus is too limited to give the impetus needed for local development. More research, more forestry technology transfer, and greater response to the changing needs of the territories are required.

Option: Congress could support natural resource agencies in U.S. territories by increasing funding for the cooperative State and Private Forestry programs of the U.S. Forest Service institutes in Puerto Rico and Hawaii. Congress could also create a program of grants to territorial governments to encourage investment in privately owned forests.

The Federal Government subsidizes private forestry with cost-sharing and direct payments to forest owners. Replacing these subsidies with a program of grants administered by the territorial governments would provide the flexibility needed to respond to each island territory's unique cultural, economic, and ecological characteristics. Furthermore, it would encourage the development of a constituency concerned with sustaining the forest resources.

27 Due in large part to increasing concerns over global climate change, tropical forest degradation, and loss of biological diversity, funds and staff for the U.S. Forest Service research institutions and Office of International Forestry have increased since the mid-1980s.

Technologies to Maintain Biological Diversity

Foreword

The reduction of the Earth's biological diversity has emerged as a public policy issue in the last several years. Growing awareness of this planetary problem has prompted increased study of the subject and has led to calls to increase public and private initiatives to address the problem.

One major concern is that loss of plant, animal, and microbial resources may impair future options to develop new important products and processes in agriculture, medicine, and industry. Concerns also exist that loss of diversity undermines the potential of populations and species to respond or adapt to changing environmental conditions. Because humans ultimately depend on environmental support functions, special caution should be taken to ensure that diversity losses do not disrupt these functions. Finally, esthetic and ethical motivation to avoid the irreversible loss of unique life forms has played an increasingly major role in promoting public and private programs to conserve particular species or habitats.

Congressional requesters of this assessment include the House Committee on Science, Space, and Technology; Senate Committee on Foreign Relations; and Senate Committee on Agriculture, Nutrition, and Forestry. The House Committee on Foreign Affairs, House Committee on Agriculture, and House Committee on Merchant Marine and Fisheries endorsed the requested study.

The task presented to OTA by these committees was to clarify for Congress the nature of the problems of reduction of the Earth's biological diversity and to set forth a range of policy options available to Congress to respond to various concerns. The principal aim of this assessment is to identify and assess the technological and institutional opportunities and constraints to maintaining biological diversity in the United States and worldwide. Two background papers *(Grassroots Conservation of Biological Diversity in the United States* and *Maintaining Biological Diversity in the United States: Data Considerations)* and a staff paper *(The Role of U.S. Development Assistance in Maintaining Biological Diversity in Developing Countries)* were also prepared in conjunction with this study.

OTA is grateful for the valuable assistance of the study's advisory panel, workgroups, workshop participants, authors of background papers, and the many other reviewers from the public and private sectors who provided advice and information throughout the course of this assessment. As with all OTA studies, the content of this report is the sole responsibility of OTA.



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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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Technologies to Maintain Biological Diversity

Most biological diversity survives without human intervention to maintain it. But as natural areas become progressively modified by human activities, maintaining a diversity of ecosystems, species, and genes will increasingly depend on intervention by applying specific technologies. A spectrum of technologies is available to support maintenance of biological diversity (defined in box A).

THE PROBLEM

The Earth's biological diversity is being reduced at a rate likely to increase over the next several decades. This loss of diversity measured at the ecosystem, species, and genetic levels is occurring in most regions of the world, although it is most pronounced in particular areas, most notably in the tropics. The principal cause is the increasing conversion of natural ecosystems to human-modified landscapes. Such alterations can provide considerable benefits when the land's capability to sustain development is preserved, but compelling evidence indicates that rapid and unintended reductions in biological diversity are undermining society's capability to respond to future opportunities and needs. Most scientists and conservationists working in this area believe the problem has reached crisis proportions, although a few people from other fields remain skeptical and maintain this level of concern is based on exaggerated or insufficient data.

The abundance and complexity of ecosystems, species, and genetic types have defied complete inventory and thus the direct assessment of changes. As a result, an accurate **estimate of the rate of loss is not currently possible.** Determining the number of species that exist,[1] for example, is a major obstacle in assessing the rate of species extinction. But use of biological principles and data on land use conversions has allowed biologists to deduce that the rate of loss is greater than the rate at which new species evolve.

Box A—What Is Biological Diversity?

Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance.

How does diversity vary within ecosystem, species, and genetic levels? For example:

- Ecosystem diversity: A landscape interspersed with croplands, grasslands, and woodlands has more diversity than a landscape with most of the woodlands converted to grasslands and croplands.
- Species diversity: A rangeland with 100 species of annual and perennial grasses and shrubs has more diversity than the same rangeland after heavy grazing has eliminated or greatly reduced the frequency of the perennial grass species.
- Genetic diversity: Economically useful crops are developed from wild plants by selecting valuable inheritable characteristics. Thus, many wild ancestor plants contain genes not found in today's crop plants. An environment that includes both the domestic varieties of a crop (such as corn) and the crop's wild ancestors has more diversity than an environment with wild ancestors eliminated to make way for domestic crops.

To date, concerns over the loss of biological diversity have been defined almost exclusively in terms of species extinction. Although extinction is perhaps the most dramatic aspect of the problem, it is by no means the whole problem. The consequence is a distorted definition of the problem, which fails to account for many of the interests concerned and may misdirect how concerns should be addressed.

[1] Approximately 1.7 million species have been identified, Millions more, however, have yet to be discovered. Recent research indicates that species of tropical insects alone could number 30 million.

Reduced diversity may have serious consequences for civilization.[2] **It may eliminate options** to use untapped resources for agricultural, industrial, and medicinal development. Crop genetic resources have accounted for about 50 percent of productivity increases and for annual contributions of about $1 billion to U.S. agriculture. For instance, two species of wild green tomatoes discovered in an isolated area of the Peruvian highlands in the early 1960s have contributed genes for marked increase in fruit pigmentation and soluble-solids content currently worth nearly $5 million per year to the tomato-processing industry. Future gains will depend on use of genetic diversity.[3]

Loss of plant species could mean loss of billions of dollars in potential plant-derived pharmaceutical products. About 25 percent of the number of prescription drugs in the United States are derived from plants. In 1980, their total market value was $8 billion. Loss of tropical rain forests, which harbor an extraordinary diversity of species, and loss of desert ecosystems, which harbor genetically diverse vegetation, are of particular concern. Consequences to humans of loss of potential medicines have impacts that go beyond economic benefits. For example, alkaloids from the rosy periwinkle flower *(Catharantus roseus),* a tropical plant, are used in the successful treatment of several forms of cancer, including Hodgkin's disease and childhood leukemia.

Although research in biotechnology suggests exciting prospects, scientists will continue to rely on genetic resources crafted by nature. For example, new methods of manipulating genetic material enable the isolation and extraction of a desired gene from one plant or organism and its insertion into another. Nature provides the basic materials; science enables the merging of desired properties into new forms or combinations. Loss of diversity, therefore,

2 To enable policymakers to give appropriate weight to diversity and other aspects of nature, analysts have developed new methods to describe the value of biological resources. Categories of values include: (1) commercial use (marketed), (2) consumptive noncommercial use (consumed, but not marketed), (3) non-consumptive use (ecological services, research, recreation),(4) option value (maintaining options for the future), and (5) ethical values regarding existence of wildlife and nature[J.A. McNeely, et al., *Conserving the World's Biological Diversity (Gland, Switzerland* and Washington DC: International Union for the Conservation of Nature and Natural Resources, 1990)].

Commercial use of biological resources is the easiest to value. For example, the estimated production value of cascara, a laxative derived in the United States from tree bark, is $1 million per year, and the retail value is $75 million per year [C. Prescott-Allen and R. Prescott-Allen, *The First Resource: Wild Species in the North American Economy (New* Haven, CT: *Yale* University Press, 1986)]. However, such statistics are useful mostly as general indicators of significance, since statistics on such "minor" products are restricted to a few items and are seldom available for the specific geographic site about which a decision is being made.

Economists have used a number of methods to assign values to biological resources. The methods usually report quantities of material consumed, such as 3 million kilograms of meat from springhare consumed annually in Botswana, or significance of the resources to peoples' welfare, such as 75% of the population of Ghana depending on wild sources of protein [C. Prescott-Allen and R. Prescott-Allen, *The FirstResource: Wild Species in the North American Economy (New* Haven, CT: Yale University Press, 1986)]. Sometimes a monetary measure is assigned by estimating the value if the directly consumed materials had been sold at prevailing market prices; by this method wild pigs harvested by hunters in Malaysia are worth $1(X) million per year [J. Caldecott, "Hunting and Wildlife Management in Sarawak," Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources, 1988].

Economists have developed methods to describe the economic loss incurred when natural potentials for environmental services, such as waste disposal, are degraded [H. Peskin and E. Lutz, "A Survey of Resource and Environmental Accounting in Industrialized Countries," World Bank Environment Department Working Paper No. 37, Washington, DC, 1990]. However, the methods have yet to be applied to biological diversity loss.

Option and ethical values seerned a few years ago to be of more concern to environmentalists than to professional resource managers. Now, American foresters and other resource managers are actively developing ways to give more weight to such option values and existence values in their management of protected natural areas and production landscapes.

Attempts to evaluate biological natural resources may begin to have more impact on policy, as methods are also being developed to adjust the conventional method of national income accounting. Gross Domestic Product (GDP) and Gross National Product (GNP) calculations, which have important scorekeeping and management functions for development policymaking, are calculated without regard to depletion of natural resource stocks. American and European economists have begun to promote changes in the conventional methods for calculating these indices that would take account of natural resources. Biodiversity as a natural resource has not yet been explicitly included in the proposed accounting revisions, but the commercial value of natural forests and topsoil has been included, as have some nonconsumptive use values& Repetto, et al., "Wasting Assets: Natural Resources in the National Income Accounts' (Washington DC: World Resources Institute, 1989); H. Peskin, "A Proposed Environmental Accounts Framework," in Ahmad, Y.J. et al. (eds), *Environmental Accounting for Sustainable Development (Washington DC:* World Bank 1989)1. Thus evaluation of biological resources is being moved beyond isolated statistics and into comprehensive analyses likely to influence development policy at national and international levels.

3 More than 200" crop species originated in tropical forests. Scientists use the genetic resources contained in the wild relatives Of those crops to breed crop resistance to pests and pathogens, such as the psyllid insect that has attacked leucaena plantations in Asia and the fungal disease blacksigatoka which is decimating bananas and plantains in many regions where these crops are the most important staples. Genetic solutions to such problems are more enduring, more environmentally benign, and less expensive than pesticides. Thus the loss of genetic diversity from tropical deforestation is expected to drive up the price of such goods as coffee, chocolate, vanilla, and tires [N.J.H. Smith, et al. "Conserving the Cornucopia" *Environment,* vol. 33, No. 6, July/August 1991, pp. 7-9,30-32].

may undermine societies' realization of the technology's potential.[4]

Another threatening aspect of diversity loss is the disruption of environmental regulatory functions that depend on the complex interactions of ecosystems and the species that support them. Diverse wetlands provide productive and protective processes of economic benefit. Millions of waterfowl and other birds of economic value depend on North American wetlands for breeding, feeding, migrating, and overwintering. About two-thirds of the major U.S. commercial fish, crustacean, and mollusk species depend on estuaries and salt marshes for spawning and nursery habitat. Wetlands temporarily store flood waters, reducing flow rates and protecting people and property downstream from flood and storm damage. One U.S. Army Corps of Engineers' estimate places the present value of the Charles River wetlands (in Massachusetts) for its role in controlling floods at $17 million per year. Although placing dollar values on such ecosystem services is problematic and reflects rough approximations, the magnitude of the economic benefit stresses the importance of these often overlooked values.[5]

Humans also value diversity for reasons other than the utility it provides. Esthetic motivations have played important parts in promoting initiatives to maintain diversity. Cultural factors, as reflected in the way Americans identify with the bald eagle or the American bison or how plants and animals form a fundamental aspect of human artistic expression, illustrate these values.

Forces that contribute to the worldwide loss of diversity are varied and complex. Historically, concern for diversity loss focused on commercial exploitation of threatened or endangered species. Increasingly, however, attention has been focused more on indirect threats that are nonselective and more fundamental and sweeping in scope.

Most losses of diversity are unintended consequences of human activity. Air and water pollution, for example, can cause diversity loss far from the pollution's source. The decline of several fish species in Scandinavia and the near extinction of a salmon species in Canada have been attributed to acidification of lakes due to acid rain. Population growth in itself may not be intrinsically threatening to biological diversity. A populous country like Japan is an example of how a high standard of living, appropriate government policies, and a predominantly urbanized population can limit the rate of ecosystem disruption. However, when population growth is compounded by poverty, a negative impact is characteristic. In many tropical developing countries, high population growth and the practice of shifting agriculture employed by peasant farmers are considered the greatest threats to diversity.

This report assesses the potential of diversity-maintenance technologies and the institutions developing and applying these technologies. But maintaining biological diversity will depend on more than applying technologies. Technologies do not exist to recreate the vast majority of ecosystems, species, and genes that are being lost, and there is little hope that such technologies will be developed in the foreseeable future. Therefore, efforts to maintain diversity must also address the socioeconomic, political, and cultural factors involved.

INTERVENTIONS TO MAINTAIN BIOLOGICAL DIVERSITY

There are two general approaches to maintaining biological diversity. It may be maintained where it is found naturally (onsite), or it may be removed from the site and kept elsewhere (offsite). Onsite maintenance can focus on a particular species or population or, alternatively, on an entire ecosystem. Offsite maintenance can focus on organisms preserved as germplasm or on organisms preserved as living collections. Table 1 lists examples of management systems. These management systems have somewhat different objectives, but all four are necessary components of an overall strategy to

4 Recent development of more cost-effective techniques to screen natural chemicals for effectiveness against diseases has led to a resurgence Of interest in development of drugs from natural plant and animal chemicals. About 75 companies and 112 research firms are developing drugs based on traditional medicines, an approach which also greatly increases the cost-effectiveness of the search for new drugs [N. Eisner, "Botanists Ply Trade in Tropics, Seeking Plant-Based Chemicals, " *The Scientist,* vol. 5, June 10, 1991, p. 12].

5 The ability of nations to adapt to the environmental changes expected to result from global warming will depend to a considerable extent on biological diversity. Substantial changes are expected in the ecosystems upon which human economies depend [J.T. Houghton, et al., "Effects on Ecosystems, " in *Climate Change: The IPPC Scientific Assessment (New* York, NY: Cambridge University Press, 1990), pp. 283-310], and the capacity of ecosystems to recuperate from change depends largely on genetic diversity [O.T. Solbrig, "The Origin and Function of Biodiversity' *Environment,* vol. 33, No. 5, 1991, pp. 16-38].

Table l—Examples of Management Systems to Maintain Biological Diversity

Onsite		Offsite	
Ecosystem maintenance	Species management	Living collections	Germplasm storage
National parks	Agroecosystems	Zoological parks	Seed and pollen banks
Research natural areas	Wildlife refuges	Botanic gardens	Semen, ova, and embryo banks
Marine sanctuaries	In-situ genebanks	Field collections	Microbial culture collections
Resource development planning	Game parks and reserves	Captive breeding programs	Tissue culture collections
		Increasing human intervention	+
+-- --	— Increasing emphasis on natural processes		

SOURCE: Office of Technology Assessment, 1986.

conserve diversity. Conservation objectives can be enhanced by investing in any combination of the four systems and by improving links to take advantage of their potential complementariness. The objectives of the management systems are summarized in table 2.

Maintaining plants, animals, and microbes onsite—in their natural environments—is the most effective way to conserve a broad range of diversity. Onsite technologies primarily focus on establishing an area to protect ecosystems or species and on regulating species harvest. To date, the guidelines for optimal design of protected areas are limited, however.

Offsite maintenance technologies are applied to conserving a small but often critical part of the total diversity. Technologies for plants include seed storage, *in vitro culture,* and living collections. Most animals are commonly maintained offsite as captive populations. Cryogenic storage of seeds, *in vitro* cultures, semen, or embryos can improve the efficiency of offsite maintenance and reduce costs.

Microbial diversity is important for both its beneficial and its harmful effects. That is, some microbes (e.g., bacteria and viruses) can present serious threats to human health. By the same token, these organisms are used in a range of beneficial activities, such as for developing vaccines or for treating wastes.

Table 2—Management Systems and Conservation Objectives

Onsite		Offsite	
Ecosystem maintenance	Species maintenance	Living collections	Germ plasm storage
Maintain:	Maintain:	Maintain:	Maintain:
• a reservoir or "library" of genetic resources	• genetic interaction between semi-domesticated species and wild relatives	• breeding material that cannot be stored in genebanks	• convenient source of germplasm for breeding programs
• evolutionary potential	• wild populations for sustainable exploitation	• field research and development on new varieties and breeds	• collections of germplasm from uncertain or threatened sources
• functioning of various ecological processes	• viable populations of threatened species	• off site cultivation and propagation	• reference or type collections as standard for research and patenting purposes
• vast majority of known and unknown species	• species that provide important indirect benefits (for pollination or pest control)	• captive breeding stock of populations threatened in the wild	• access to germplasm from wide geographic areas
• representatives of unique natural ecosystems	• "keystone" species with important ecosystem support or regulating function	• ready access to wild species for research, education, and display	• genetic materials from critically endangered species

SOURCE: Office of Technology Assessment, 1986.

Scientists are hampered in their storage, use, and study of microbial diversity by their inability to isolate most microorganisms. For those microorganisms that have been isolated and identified, offsite maintenance is the most cost-effective technique.

Links between onsite and offsite management systems are important to increasing the efficiency and effectiveness of efforts to maintain diversity. Some technologies developed for domesticated species, for instance, can be adapted to wild species. Embryo transfer technologies developed for livestock are now being adapted for endangered wild animals,

Determining the efficacy and appropriateness of technologies depends on biological, sociopolitical, and economic factors. Taken together, these factors influence decisionmaking and must be considered in defining objectives for maintaining diversity and for identifying strategies to meet these objectives.

Biological considerations are central to the objectives and choice of systems. Only some diversity is threatened; therefore, the task of maintaining it can focus on elements that need special attention. A biologically unique species (one that is the only representative of an entire genus or family) or a species with high esthetic appeal may be the focus of intensive conservation management.

Political factors also influence conservation objectives and management systems. Commitments of government resources, policies, and programs determine the focus of attention, and to a large extent, such commitments reflect public interests and support. For example, a disproportionate share of U.S. resources is devoted to programs for a few of the many endangered species.[6] Substantial sums have been spent in 1lth-hour efforts to save the California condor and the black-footed ferret, while other endangered organisms such as invertebrate species receive little attention.

The applicability of management systems also depends on economic factors. Costs of alternative management systems and the value of resources to be conserved may be relatively clear in the case of genetic resources. For example, the benefits of plant breeding programs compared with the cost of seed maintenance justify germplasm storage technologies, However, cost-benefit analysis is more difficult when benefits are diffuse and accrue over a long period. And onsite maintenance programs compete with other interests for land, personnel, and funds.

Success in maintaining biological diversity depends largely on institutions that develop and apply the various technologies. Within the United States, a variety of laws in addition to public and private programs address various aspects of diversity conservation. But while some aspects of diversity are covered, other aspects are ignored. Table 3 lists major Federal mandates pertinent to diversity maintenance.

Because U.S. interest in biological diversity extends beyond its borders, the United States subscribes to a number of international conservation laws and supports programs through bilateral and multilateral assistance channels. However, many of these programs have too little support to be effective in resolving internationally important problems.

Domestic and international institutions deal with aspects of diversity. Some focus attention exclusively on maintaining certain agricultural crops, such as wheat, and others focus on certain wild species, such as whales and migratory waterfowl. A shift has occurred in recent years from the traditional species protection approach to a more encompassing ecosystem maintenance approach.

Much of the work important to diversity maintenance is done in isolation and is too disjunct to address the full range of concerns. And some concerns receive little or no attention, For example, the objectives of the U.S. Department of Agriculture's National Plant Germplasm System (NPGS) place primary emphasis on economic plants and little emphasis on non-crop species. Similarly, programs to protect endangered wild species direct attention away from species that are threatened but not listed as endangered. The lack of connections between programs is another institutional constraint. Linkages help define common interests and areas of potential cooperation—important steps in defining areas of redundancy, neglect, and opportunity.

[6] A substantial portion of Federal Government investments focused on U.S. biodiversity continue to be allocated in response to threats to species, largely due to Endangered Species Act processes. U.S. development assistance funds focused on biodiversity, on the other hand, arc focused more on multl-species habitat protection, research to determine priorities and develop projects that arc usually focused on ecosystems, and activities to support development of pollers that will lead to ecosystem maintenance [U.S. Department of Agriculture, Forestry Support Program, "USAID Environment Sector Analysis: 1991, ' Rockvillc, MD: ICT, Inc., 1991].

Table 3-Federal Laws Relating to Biological Diversity Maintenance

Common name	Resource affected	U. S. Code
Onsite diversity mandates:		
Lacey Actof 1900..	wild animals	16 U.S.C. 667, 701
Migratory Bird Treaty Act of 1918.	wild birds	16 U.S.C. 703 et seq.
Migratory Bird Conservation Act of 1929.	wild birds	16 U.S.C. 715 et seq.
Wildlife Restoration Act of 1937 (Pittman-Robertson Act).	wild animais	16 U.S.C. 669 et seq.
Bald Eagle Protection Act of 1940.	wild birds	16 U.S.C. 668 et seq.
Whaling Convention Act of 1949.	wild animals	16 U.S.C. 916 et seq.
Fish Restoration and Management Act of 1950 (Dingell Johnson Act).	fisheries	16 U.S.C. 777 et seq.
Anadromous Flsh Conservation Act of 1965 (Public Law 89-304).	fisheries	16 U.S.C. 757a-f
Fur Seal Act of 1966 (Public Law 89-702).	wild anirnals	16 U.S.C. 1151 et seq.
Marine Mammal Protection Act of 1972	wild animals	16 U.S.C. 1361 et seq.
Endangered Species Act of 1973 (Public Law 93-205).	wild plants and animals	7 U.s.c. 136 16 U.S.C. 460,668,715, 1362,1371,1372,1402, 1531 et seq.
Magnuson Fishery Conservation and Management Act of 1977 (PublicLaw 94-532).	fisheries	16 U.S.C. 971, 1362, 1801 et seq.
Whale Conservation and Protection Study Act of 1976 (Public Law 94-532).	wild animals	16 U.S.C. 915 et seq.
Fish and Wildlife Conservation Act of 1980 (Public Law 96-366).	wild animals	16 U.S.C. 2901 et seq.
Salmon and Steelhead Conservation and Enhancement Act of 1980 (Public Law 96-561)	fisheries	16 U.S.C. 1823 et seq.
Fish and Wildlife Coordination Act of 1934.	terrestrial/aquatic habitats	16 U.S.C. 694
Flsh and Game Sanctuary Act of 1934.	sanctuaries	16 U.S.C. 694
Historic Sites, Buildings,and Antiquities Act of 1935.	natural landmarks	16 U.S.C. 461-467
Fish and Wildlife Act of 1956.	wildlife sanctuaries	15 U.S.C. 713 et seq. 16 U.S.C. 742 et seq.
Wilderness Act of 1964 (PublicLaw 88-577).	wilderness areas	16 U.S.C. 1131 et seq.
National Wildlife Refuge System Administration Act of 1966 (PublicLaw91-135).	refuges	16 U.S.C. 668dd et seq.

THE ROLE OF CONGRESS

Given the implications and irreversible nature of biological extinction, policymakers must continue to address the problem of diminishing biological diversity. A significant increase in attention and funding in this area seems consistent with U.S. interests, in view of the benefits the United States currently derives from biological diversity and the advances that biotechnology might achieve given a diversity of genetic resources. In addition, enough information exists to define priorities for diversity maintenance and to provide a rationale for taking initiatives now, although further research and critical review of the nature and extent of diversity loss are also warranted.

Table 3-Federal Laws Relating to Biological Diversity Maintenance-Continued

Common name	Resource affected	U.S. Code
Wild and Scenic Rivers Act of 1968 (Public Law 90-542).	river segments	16 U.S.C. 1271-1287
Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532).	coastal areas	16 U.S.C. 1431-1434 33 U.S.C. 1401.1402, 1411-1421, 1441-1444
Federal Land Policy and Management Act of 1976 (Public Law 94-579).	public domain lands	7 U.s.c. 1010-1012 16 U.S.C. 5, 79,420,460, 478,522,523,551,1339 30 U.s.c. 50,51, 191 40 U.s.c. 319 43 U.S.C. 315,661,664, 665,687,869,931,934-939,942-944,946-959,961-970, 1701, 1702,1711-1722,1731-1748,1753,1761-1771, 1781, 1782
National Forest Management Act of 1976 (Public law 94-588)	national forest lands	16 U.S.C. 472,500,513, 515,516,518,521,576, 581, 1600, 1601-1614
Public Rangelands Improvement Act of 1978 (Public law 95-514)	public domain lands	16 U.S.C. 1332, 1333 43 U.s.c. 1739, 1751-1753.1901-1908
Offsite diversity mandates:		
Agricultural Marketing Act of 1946 (Research and Marketing Act).	agricultural Plants and animals	5 U.s.c. 5315 7U.S.C. 1006,1010,1011, 1924-1927,1929,1939-1933,1941-1943,1947, 1981,1983,1985,1991, 1992,2201,2204,2212, 2651-2654, 2661-2668 16 U.S.C. 590, 1001-1005 42 U.S.C. 3122
Endangered Species Act of 1973 (Public 93-205).	wild plants and	7 U.s.c. 136 16 U.S.C. 460,668,715, 1362,1371,1372,1402, 1531 et seq.
Forest and Rangeland Renewable Resources Research Act of 1978 (Public Law 95-307).	tree germplasm	16 U.S.C. 1641-1647

NOTE: Laws enacted prior to 1957 are cited by Chapter and not Public Law number.

SOURCE: Office of Technology Assessment, 1986.

OTA has identified options available to Congress. These options are discussed under five major issues:

1. strengthening the national commitment,
2. increasing the Nation's ability to maintain biological diversity,
3. enhancing the knowledge base,
4. supporting international initiatives, and
5. addressing loss of biological diversity in developing countries.

For each issue, alternative or complementary options are presented. These range from legislative initiatives to program changes within Federal agencies. Options also define opportunities to cultivate Or support private-sector initiatives. In a number of areas, however, success will depend on increased or

Table 4—Summary of Policy Issues for Congressional Action Related to Biological Diversity Maintenance

Issue	Finding	Options
Strengthen national commitment	Adopt a comprehensive approach to maintaining biological diversity	Establish a national biological diversity act Prepare a national conservation strategy Amend appropriate legislation of Federal agencies
	Increase public awareness of biological diver sit y issues	Establish a national conservation education act Amend the international Security and Development Cooperation Act
increase ability to maintain biological diversity	Improve research, technology development and application	Direct Nationalk Science Foundation to to establish a conservation biology program Establish a national endowment for biological diversity
	Fill gaps and inadequacies in existing programs	Provide sufficient funding for existing maintenance programs Improve i ink between on site and offsite programs Establish new programs to fill specific gaps in current efforts
Enhance knowledge base	Improve data collection, maintenance, and use	Establish a clearinghouse for biological data Enhance existing natural heritage network of conservation data centers
Support international initiatives	Provide greater leadership in the international arena	Increase support of existing international programs Continue oversight hearings of multilateral development banks' activities
	Promote the exchange of genetic resources	Examine U.S. options on international exchange of germplasm Amend the Export Administration Act to affirm U.S. commitment to free exchange of germpiasm
Address loss in developing countries	Amend Foreign Assistance Act	Adopt broader definition of biological diversity in Foreign Assistance Act
	Enhance capability of the Agency for International Development	Direct AID to adopt strategic approach to diversity conservation increase AID staffing of personnel with environmental-training
	Establish alternative funding sources for biological diversity projects	Create special account for natural resources and the environment Apply more Public Law 480 funds to effort

SOURCE: Office of Technology Assessment, 1987.

redirected commitments of resources. Table 4 provides a summary of policy issues and options.

Strengthen the National Commitment to Maintain Biological Diversity

The national commitment to maintain biological diversity could be strengthened. Despite society's reliance on biological resources for sustenance and economic development, loss of diversity has yet to emerge as a major concern among decisionmakers. About 2 percent of the national budget is spent on natural resources-related programs, which include diversity-conservation programs as one subset.

A number of government and private programs address maintenance of biological diversity, but most programs have objectives too narrowly defined to address the broad scope of biological diversity concerns. Nor do the ad hoc programs use coordination and cooperation to build **a** systematic approach to tackle the issue. State and private efforts fill some gaps in Federal programs, but they do not provide a comprehensive national commitment and thus leave many aspects of the problem uncovered.

Federal agencies, for example, coordinate the onsite conservation activities mentioned specifically in Federal species protection laws, such as those

under the authority of the Endangered Species Act of 1973 (Public Law 93-205), but no formal institutional mechanism exists for the thousands of plant, animal, and microbial species not listed as threatened or endangered. Mandates for offsite conservation are equally vague about which species they are to consider. For example, the Research and Marketing Act of 1946 is intended to 'promote the efficient production and utilization of products of the soil' (7 U. S.C.A. 427), but it is interpreted narrowly by the Agricultural Research Service (ARS) to *mean eco*nomic plant species and varieties. Thus, little government attention has been given to conserving the multitude of wild plant species offsite. Even less attention is given to offsite conservation of domesticated and wild animals.

FINDING 1: A comprehensive approach is needed to arrest the loss of biological diversity. Significant gaps in existing programs could be identified with such an approach, and the resources of organizations concerned with the **issue** could be better allocated. Improved coordination could create opportunities to enhance effectiveness and efficiency of Federal, State, and private programs without interfering with achievement of the programs' goals.

The broad scale of the problem of diversity loss necessitates innovative solutions. Various laws and programs of Federal, State, and private organizations already provide the framework for a concerted comprehensive approach. At this time, however, few of these programs state maintenance of biological diversity as an explicit objective. As a result, diversity is given cursory attention in most conservation and resource management programs. Some of them, such as the Endangered Species Program, address diversity more directly but are concerned with only one facet of the problem. Duplication of efforts, conflicts in goals, and gaps in geographic and taxonomic coverage are consequences.

To resolve this institutional problem, a comprehensive approach to maintaining biological diversity is needed. The implication is not that all programs should address the full range of approaches; rather, organizations should view their own programs within the broader context of maintaining diversity and should coordinate their programs with those of other organizations. Programs and organizations would thereby benefit from one another. Gaps could be identified and eventually filled, and duplicate efforts could be reduced. And organizations could improve efficiency by taking the responsibilities for which they are best suited. Moreover, financial support for diversity maintenance could be more effectively distributed. A step in this direction has been taken in recent initiatives, but congressional commitment to such an endeavor is necessary to ensure that efforts will be made to achieve a comprehensive approach to maintaining biological diversity.

Option 1.1: Enact legislation that recognizes the importance of maintaining biological diversity as a national objective.

Current legislation addressing the loss of biological diversity in the United States is largely piecemeal. Although many Federal laws affect conservation of diversity, few refer to it specifically. The National Forest Management Act of 1976 is the only legislation that mandates the conservation of a ''diversity of plant and animal communities,' but it offers no explicit direction on the meaning and scope of diversity maintenance.

Consequently, existing Federal programs focus on sustaining specific ecosystems, species, or gene pools, or on protecting endangered wildlife. Species protection laws authorize Federal agencies to manage specific animal populations and their habitats. Habitat protection laws authorize the acquisition or designation of habitats under Federal stewardship. Federal laws for offsite maintenance of plants authorize the collection and genetic development of plant species that demonstrate potential economic value.

The Endangered Species Act authorizes protection of species considered threatened or endangered in the United States. However, listing endangered species does not eliminate the problem; efforts are hampered by slow listing procedures, by emphasis on vertebrate animals at the expense of plants and invertebrates, and by concerns about conflicts that endangered status might create.

Congress could pass a National Biological Diversity Act to endorse the importance of the issue and to provide guidance for a comprehensive approach. Such an act could explicitly state maintenance of diversity as a national goal, establish mechanisms for coordinating activities, and set priorities for diversity conservation. A national policy could

bring about cooperation among Federal, State, and private efforts, help reduce conflicting activities, and improve efficiency and cost-effectiveness of programs.

To be effective, anew act would require a succinct definition of biological diversity and explicit goals for its maintenance. Otherwise, ambiguities would lead to misinterpretation and confusion. Diversity, for example, could be interpreted broadly when authorities and funding are being sought and narrowly when responsibilities are assigned. Identifying goals is likely to be a long and politically sensitive process. Decisionmakers and the public will have to determine if conserving maximum diversity is the desirable goal. Finally, to be effective, the law must have public support and adequate resources, or it would simply provide a false reassurance that something is being done.

Option 1.2: Develop a National Conservation Strategy for U.S. biological resources.

Another means of comprehensively addressing diversity maintenance is to develop a National Conservation Strategy (NCS). This strategy could be developed in conjunction with, or in lieu of, a mandate as suggested in the preceding option. The process would initiate coordination of Federal programs. Program administrators could identify measures to reduce overlap and duplication, to minimize jurisdictional problems, and to develop new initiatives.

A national strategy could minimize potential competition, conflict, and duplication among programs in the private and public sectors. In addition, preparation of an NCS would strengthen efforts to promote NCSs in other countries. Some 30 countries (mostly developing countries, but also including Canada and the United Kingdom) have initiated concrete steps to prepare an NCS. U.S. action might reinforce the momentum for NCSs in other countries.

Congress could establish an independent commission to prepare the NCS. Members of the commission could serve part-time and be provided a budget for meetings and administrative support. The commission could include representatives from government, academia, and the private sector. The Public Land Law Review Commission and the National Water Commission are potential models.

In developing a national strategy, such a commission could do the following:

- assess the adequacy of existing programs to conserve biological diversity;
- formulate a national policy on maintenance of biological diversity;
- identify measures required to implement the policy, any obstacles to such measures, and the means to overcome those obstacles;
- determine how biological diversity maintenance relates to other conservation and development interests; and
- include a public consultation and information program to build a consensus on the content of the national conservation strategy.

Another way to prepare a strategy is to tap the resources of an established government agency. An appropriate body could be the Council for Environmental Quality (CEQ), which is part of the Office of the President. Created by the National Environmental Policy Act of 1969, CEQ already prepares annual reports for the President on the state of the environment. In doing so, it uses the services of public and private agencies, organizations, and individuals and hence has the experience and authority to bring together various interest groups and expertise. On the other hand, CEQ, though fully staffed in the 1970s with a range of environmental experts, now has only a small staff of administrators. Coordinating and guiding the substantive development of an NCS is thus beyond the council's current capacity except through use of consultants.

Because the success of an NCS depends on participation of a broad spectrum of interest groups, its preparation could be a daunting prospect. The number, size, and nature of U.S. Government agencies and the different sectors involved could make preparation and implementation of a strategy difficult.

Option 1.3: Amend the legislation of Federal agencies to make maintenance of biological diversity an explicit consideration in their activities.

Yet another means for Congress to encourage a comprehensive approach is to make maintenance of biological diversity an explicit consideration of Federal agencies' activities. A number of Federal programs affecting biological diversity are scattered throughout different agencies, but the lack of coordi-

nation results in inefficient and inadequate coverage of the problem.

These amendments could involve the creation of new programs, or they could lead to modified objectives for existing programs. In either case, the amendments should redirect certain policies, consolidate conservation efforts, and provide criteria for settling conflicts. An amendment for Federal land managing agencies, for example, could require that these agencies make diversity conservation a priority in decisions relating to land acquisition, disposal, and exchange.

Such amendments would probably be resisted by individual Federal agencies, which could argue they are already maintaining diversity and do not need more explicit direction from Congress. In addition, agencies could argue they could not increase their activities without new appropriations; otherwise, the quality of existing work could be compromised.

Before such amendments are written, a systematic review of all Federal resource legislation will be needed to determine how existing statutory mandates and programs affect the conservation of diversity and how they complement or contradict one another, and to designate which programs are most in need of revision. Such a complex review will take time and money and is likely to be opposed by agencies.

FINDING 2: Because maintenance of biological diversity is a long-term problem, policy changes and management programs must be long--lasting to be effective. Such policies and **programs must be understood and accepted by the public, or they will be replaced or overshadowed by shorter-term concerns. Conveying the importance of biological diversity requires formulating the issue in terms that are technically correct yet understandable and convincing to the general public. To undertake the initiative will require not only biologists but also social scientists and educators working together.**

Diversity loss has not captured public attention for three reasons. First, it is a complex concept to grasp. Rather than attempt to improve understanding of the broad issue, organizations soliciting support have made emotional appeals to save particular appealing species or spectacular habitats. This approach is effective in the short term, but it keeps



Photo credit: Alison L. Hess, Office of Technology Assessment

Most public attention to conservation of biodiversity is based on efforts to save emotionally-appealing species (commonly called "charismatic megafauna") such as the mountain gorilla, black rhinoceros, or the black-maned lion shown here.

the constituency and the scope of the problem narrow. Second, the more pervasive threats to diversity, such as loss of habitat or diminished genetic bases for agricultural crops, are gradual processes rather than dramatic events. Third, most benefits of maintaining diversity are often diffuse, unpriced, and reaped over the long term, resulting in relatively low economic values being assigned to the goods and services provided. The benefits of diversity, therefore, are not presented concretely and competitively with other issues. Consequently, the public and policymakers generally lack an appreciation of possible consequences of diversity loss.

Notwithstanding these difficulties, environmental quality has been a major public policy concern since the 1970s, and it remains firmly entrenched in the consciousness of the American public. A 1985 Harris poll, for example, indicated that 63 percent of Americans place greater priority on environmental clean-up than on economic growth. And because

stewardship of the environment includes maintaining diversity, this predisposition of Americans could be built on to develop support for diversity maintenance programs.

Biological diversity benefits a variety of special interest groups; its potential constituency is enormous but fragmented. It includes, for example, the timber and fishing industries as well as farmers, gardeners, plant breeders, animal breeders, recreational hunters, indigenous peoples, wilderness enthusiasts, tourists, and all those who enjoy nature. The combined interests of all these groups could cultivate a national commitment to maintaining biological diversity, if properly orchestrated.

Option 2.1: Promote public education about biological diversity by establishing a National Conservation Education Act,

Just as sustaining support to enhance environmental quality required public education programs, so too will a concerted national effort to conserve biological diversity require a strong public education effort. A National Conservation Education Act could be patterned after the Environmental Education Act of 1971 (Public Law 91-516), which authorized the U.S. Commissioner of Education to establish education programs to encourage understanding of environmental policies.[7]

A new act could support programs and curricula to promote, among other things, the importance of biological diversity to human welfare. A small grants program could support research and pilot public education projects. Funds could be made available to evaluate methods for curricula development, dissemination of curricula, teacher training, ecological study center design, community education, and materials for mass media programs. The act could support interaction among existing State environmental education programs, such as those in Wisconsin and Minnesota, and encourage establishment of new programs in other States. The Department of Education could provide consulting services to school districts to develop education programs.

An attempt to establish additional environmental education legislation might be opposed because of the trend to reduce the Federal Government's role in education and to rely more on State find private-sector initiatives. Therefore, it could be argued that private organizations, such as the Center for Environmental Education, are the appropriate agents to increase public awareness. It could also be argued that Federal agencies are already educating the public about environmental issues and could easily include biological diversity in their programs without new legislation.[8] Besides, new legislation would require additional appropriations, and in a time of budgetary constraints, funding requests for conservation education programs would probably be opposed.

Option 2.2: Amend the International Security and Development Act of 1980 to increase the awareness of the American public about international diversity conservation issues that affect the United States.

Even more difficult than increasing the public's awareness of domestic issues in biological diversity is increasing their awareness of the relevance of diversity loss in other countries. In addition to humanitarian and ethical reasons, maintaining diversity in other countries benefits the United States by Sustaining biological resources needed for American agriculture, pharmacology, and biotechnology industries, and by sustaining natural resources necessary for commerce and economic development.

Maintaining biological diversity for security and quality of life enhancement, and the wisdom of incorporating such issues into U.S. foreign assistance efforts, are justification for Congress to promote public awareness of the global nature of the problem.

Mechanisms for educating the public about such international issues are already in place. Specifically, several nongovernmental organimations (NGOs) have international conservation operations. A coalition of these groups actively participated in the U.S. Interagency Task Force on biological diversity that formulated the *U.S. Strategy on the Conservation of*

7 This act was repealed by Public Law 97-35 in 1981.

8 While a comprehensive national conservation education program has not re-emerged, Federal agencies do support the numerous programs that provide information and educational materials on various facets of environmental issues, often including biological diversity. For example, the Center for Marine Conservation (formerly the Center for Environmental Education mentioned in the text), has programs sponsored by NOAA and EPA that provide educational materials on ocean pollution for primary and secondary teachers and students.

Biological Diversity in Developing Countries. As a group, they have identified public education as a major role for NGOs.

The grassroots approach of NGOs is conducive to heightening public awareness, as illustrated by the support for programs to alleviate famine in Africa. Recognizing the potential of NGOs to stimulate public awareness and discussion of the political, economic, technical, and social factors relating to world hunger and poverty, Congress amended the International Security and Development Cooperation Act of 1980 with Title III, Section 316, to further the goals of Section 103.[9]

This amendment provides NGOs with Biden-Pell matching grants to support programs that educate U.S. citizens about the links between American progress and progress in developing countries. The Agency for International Development (AID) has used these grants mainly to promote American understand ing of the problems faced by farmers in developing countries and how resolution of those problems benefits Americans. Recently, use of the grants has been broadened to include public education on international environmental issues. *Congress could encourage this action by expressing its approval during oversight hearings or by further amending the International Security and Development Cooperation Act specifically to authorize support for education programs on environmental issues, especially on biological diversity.*

Increase the Nation Ability to Maintain Biological Diversity

The ability to maintain biological diversity depends on the availability of applicable technologies that are useful and affordable and on programs designed to apply these technologies to clearly identified needs. Thus, increasing the Nation's ability to maintain diversity will require an improved system for identifying needs and for developing or adapting technologies and programs to address these needs.

At present, technologies and programs are not sufficient to prevent further erosion of biological resources. The problem of diversity loss has been recognized relatively recently, and scientists have just begun to focus attention on it. Progress is slow partly because basic research is poorly funded, and institutions are not organized to follow up basic research with synthesis of results, technology development, and technology transfer. The last reason implies a need for goal-oriented research.

Many of the Nation's current research programs related to biological diversity do not have a goal-oriented approach. Institutional reward systems and prestige factors deter many scientists from engaging in work that translates basic science into practical tools. Several Federal agencies support basic biology and ecology research, but too little support exists for synthesis of the research into technologies.

Improved links between research and management systems, that is, technology transfer, can increase efficiency, effectiveness, and ability for maintaining g diversity. For example, understanding how to maintain and propagate wild endangered species has been preceded by efforts to maintain domestic species. Perhaps the most dramatic linkage is embryo transfer technology developed for livestock now being adapted for endangered wildlife. Similarly, plant storage technologies developed for



Photo credit: Alison L. Hess, Office of Technology Assessment

Interspecific embryo transfer involves transfer of embryos between related species so that embryos of a rare species could be carried to term by a female of a more common species. Successful transfers have occurred from mouflon (wild sheep) to domestic sheep, guar to cattle, bongo to eland, **Przewalski's** horse to pony, and zebra to horse.

[9]Sec. 103, entitled ''Agriculture, Rural Development and Nutrition, '' recognizes that the majority of people in developing countries live in rural areas and close to subsistence. It authorizes the President to furnish assistance to alleviate hunger and malnutrition, enhance the capacity of rural people, and to help create productive on- and off-farm employment. Sec. 316 encourages private and voluntary organizations to facilitate widespread public discussion, analysis, and review of the issues of world hunger. It especially calls for increased public awareness of the political, economic, technical, and social factors affecting hunger and poverty.

agricultural varieties, such as cryogenics and tissue culture, maybe valuable tools for maintaining rare or threatened wild plant species, even if only as backup collections.

FINDING 3: Current technologies **are insufficient to prevent further erosion of biological resources. Thus, increasing the Nation's ability to maintain biological diversity will require acceleration of basic research as well as research in development and implementation of resource management technologies.**

Most resource management technologies were developed to meet narrow needs. Onsite technologies are generally directed toward a particular population or species, and offsite technologies are generally directed toward organisms of economic importance. This restricted focus of basic research and technology development is not sufficient to meet the broad goal of maintaining diversity, given the number of species involved and the time and funds available.

To accelerate research and application of diversity-conserving technologies, a shift of emphasis is necessary in research funding. Agencies that fund or conduct research (e.g., the National Science Foundation (NSF) and the Agricultural Research Service of the USDA) generally do not focus on applying research to technology development; they mostly are oriented toward supporting basic research. For example, research funds are available for descriptive studies of population genetics but not for studies on applications of genetic theory to onsite population management. Scientists are rewarded for research that tests hypotheses relatively quickly and for publication of research results in academic journals. These incentives discourage broad, long-term studies and neglect analyzing research results to develop technology systems.

Another avenue to increasing the ability to maintain diversity is to encourage development and implementation of programs by private organizations. Although many private efforts are not defined in terms of diversity conservation per se, activities to conserve aspects of diversity (i.e., ecosystems, wild species, agricultural crops, and livestock) have had significa.nt impact. These efforts are not likely to replace public or national programs, but they could be an integral part of the Nation's attempt to maintain its biological heritage.

Option 3.1: Direct the National Science Foundation to establish a program for conservation biology.

The field of conservation biology seeks to develop scientific principles and then apply those principles to developing technologies for diversity maintenance. Recently, the development of this discipline has gained momentum through the establishment of study programs at some universities and the formation of a Society of Conservation Biology, with its own professional journal. Nevertheless, conservation biology is only beginning to be recognized by the academic community as a legitimate discipline. No research funds support it explicitly. Therefore, few scientists can afford to conduct innovative conservation biology research.

Current funding for research and technology development in conservation biology is negligible, in large part because NSF considers it to be too applied, while other government agencies consider it to be too theoretical. *Congress could encourage scientists to specialize in conservation biology by establishing within NSF a separate conservation biology research program that would support the broad spectrum of basic and applied research directed at developing and applying science and technology to biological diversity conservation.*

To enhance interprogram links, this program could fund studies that integrate onsite and offsite methods at the ecosystem, species, and genetic levels. Such a program would also bring much needed national recognition, research funding, and scientific expertise to the field of conservation biology. This support would accelerate its acceptance and growth within the scientific community and the development of new principles and technology. Current statutory authority of NSF would cover such a program. NSF programs are supposed to support basic and applied scientific research relevant to national problems involving public interest; the maintenance of biological diversity is such a problem.

NSF might resist establishing such a program, because NSF views conservation biology as a mission-oriented activity. Since conservation biology includes technology development, NSF might view a diversity program as a potentially dangerous precedent to its role as the Nation's major supporter of basic research. Furthermore, NSF might argue that a new research program is not needed because its Division of Biotic Systems and Resources

already supports about 60 basic research projects that address biological diversity issues. These projects, however, largely ignore the social, economic, political, and management aspects of biological diversity, and conservation is usually of secondary importance to the projects.

An alternative to establishing an NSF program could be to enhance or redirect existing programs in other agencies to promote research in diversity maintenance. The Institute of Museum Services (IMS), a federally sponsored program, already provides a small amount of funding for research on both onsite and offsite diversity maintenance. IMS supports activities from ecosystem surveys to captive breeding. However, the principal focus of IMS is public education, and its small budget is spread over a wide range of programs (e. g., art museums and historic collections), many of which are unrelated to biological research. Thus, IMS would be unable, with its current funding, to take greater responsibility for technology development; new appropriations would be necessary.

Development and application of diversity-conserving technologies could also be funded through other Federal agencies' research programs. *Congress could encourage appropriate agencies to increase emphasis on development of diversity technology.* One source of funding is through the USDA Competitive Research Grants Office (CRGO). At present, the only research related to genetic resources funded by USDA/CRGO is in the area of molecular genetics. As a result, little funding is available for scientists seeking to conduct research in germplasm preservation, maintenance, evaluation, and use.

Option 3.2: Establish a National Endowment for Biological Diversity.

Congress could establish a National Endowment for Biological Diversity to fund private organizations in research, education, training, and maintenance programs that support the conservation of biological diversity. Currently, no central institution funds such efforts.

Efforts, however piecemeal, of private organizations and individuals are currently making significant contributions to the maintenance of the Nation's diversity. Frequently, they undertake activities Federal and State agencies cannot or do not address. Through their special interests, these groups as a whole also play a major role in raising public awareness and concern about the loss of diversity. In this way, they increase the constituency backing government programs that maintain natural areas as well as those that collect and safeguard genetic resources.[10] Finding, however, is a major constraint for nearly all these private activities. A program of small grants with a ceiling of perhaps $25,000 per grant (similar to the grants awarded by IMS) could make a substantial contribution to the shoestring budgets of these small organizations and thus enhance national efforts to maintain biological diversity at relatively little cost.

A National Endowment for Biological Diversity could provide funds to private organizations to carry out the following:

- support research and application of methods to conserve biological diversity,
- award fellowships and grants for training,
- foster and support education programs to increase public understanding and appreciation of biological diversity, and
- buy necessary equipment such as small computers.

This national endowment could be created by amending the act that authorizes other national endowment (of arts and humanities) programs. The National Foundation on Arts and Humanities Act of 1965 (Public Law 89-209) declares that national progress is of Federal concern and supports scholarships, research, the improvement of education facilities, and encouragement of greater public awareness.

A major constraint to establishing an endowment is the availability of funds during this period of severe budget cutbacks. However, even a small program could significantly encourage private-sector initiatives in diversity maintenance. Thus, the total amount needed for such an endowment could be modest, and it might be feasible to use onIy startup funds and a partial contribution from the Federal Government and raise the remainder of the endowment from private-sector contributions.

10 For further discussion, see U.S. Congress, Office of Technology Assessment Grassroots *Conservation of Biological Diversity in the United States*, Background Paper #l, OTA-BP-F-38 (Springfield, VA: National Technical Information Service, February 1986).

FINDING 4: Many Federal agencies sponsor diversity maintenance programs that are well designed but not fully effective in achieving their objectives because of inadequate funding and personnel, lack of links to other programs, or lack of complementary programs in related fields.

Much is already being done to maintain certain aspects of diversity in the United States, but efforts are constrained by shrinkfi g budgets and personnel. And as noted earlier, the programs addressing biological diversity are piecemeal rather than comprehensive or strategic. Whether or not Congress chooses to promote a comprehensive strategy for diversity maintenance, specific attention is needed to remedy the major gaps and inadequacies in existing programs.

Option 4.1: Provide increased funding to existing programs for maintenance of diversi~.

A number of governmental programs for diversity maintenance already exist, some because of congressional mandates. Yet the full potential of some of those programs has not been realized because funding is insufficient. Two such programs are the National Plant Germplasm System (NPGS) and the Endangered Species program, though others would also benefit from higher levels of funding.

The NPGS of the Agricultural Research Service has functioned for years on severely limited funds and, consequently, is in danger of losing some of the storehouse of plant germplasm. This desperate situation is best illustrated by the National Seed Storage Laboratory (NSSL), which is expected to exceed its storage capacity in 2 years. At the same time, NSSL is being pressured to increase collection and maintenance of wild plant germplasm. NPGS is attempting to respond to various criticisms about its



Photo credit: Ken Hammond, USDA Forest Service

Critical habitat for the endangered northern spotted owl has only recently been designated, and is generating substantial controversy among private landowners, public land-users, and proponents of owl conservation programs in the Pacific Northwest. U.S. Forest Service research teams currently are studying the spotted owl and its old-growth forest habitat to refine estimates of population and areal extent of critical habitat, and to identify steps for recovery programs. Many species listed as endangered still await designation of critical habitat.

effectiveness,[11] but progress has been slow because of lack of funds and personnel. The 1986 appropriation for germplasm work is approximately $16 million, but to support current programs adequately would cost about $40 million (198 1 dollars) annually.

Similarly underfunded and understaffed is the Endangered Species Program of the Fish and Wildlife Service. A review of this program shows a substantial and growing backlog of important work. The rate of proposing species for the threatened and endangered list is so slow that a few candidates (e.g., Texas Henslow's sparrow) may have become extinct while awaiting listing. Critical habitat has been determined for only one-fourth of the listed species, and recovery plans have been approved for only some of the listed species.

Congress could provide adequate funding for these and other programs to achieve their goals in maintaining diversity, NPGS could, as a result, increase the viability of stored germplasm through more frequent testing and regeneration of accessions. NSSL could increase its efficiency by expanding storage capacity and adopting new technologies. For example, cryogenic storage could be used to reduce maintenance cost and space, thereby enabling a larger collection of germplasm. Likewise, the Endangered Species Program would be able to assess candidate species faster to develop and implement recovery plans for those already listed species.

Option 4.2: Amend appropriate legislation to improve the link between onsite and offsite maintenance programs.

Coordination between onsite and offsite programs is inadequate. *By amending appropriate legislation, Congress could encourage the complementary use of onsite and offsite technologies.* For example, the Endangered Species Act could be amended to encourage use of captive breeding and propagation techniques. Such methods have been used with some endangered species, such as the red wolf, whooping crane, and grizzly bear. But for other species, such as the California condor, black-footed ferret, and dusky seaside sparrow, recovery plans do not exist or were too long delayed. Recovery plans for endangered species seldom include the use of offsite techniques, partly because captive breeding and propagation are outside the scope of natural resource management agencies; rather, they are in the province of zoos, botanic gardens, arboretums, and agricultural research stations.

By mandating that recovery plans give specific consideration to captive breeding and propagation. Congress could encourage links between separate programs. The approach could be broadened to encourage cooperative efforts between public and private organizations working offsite and onsite to conserve ecosystem and genetic diversity. A model for such efforts exists in the emerging cooperation between the Center for Plant Conservation (a network of regional botanic institutions) and NSSL.

Option 4,3: Establish programs to fill gaps in current efforts to maintain biological diversity.

One of the most obvious gaps in domestic programs is the lack of a formal national program to maintain domestic animal genetic resources. *Congress could establish a program to coordinate activities for animal germplasm conservation, thereby reducing duplication and encouraging complementary actions.* Such a program could be established through clarification of the Agricultural Research Service mandate. An animal program could parallel the National Plant Germplasm System, but other structures should be explored as well. Alternatively, a separate program established to be semi-independent from government agencies might serve a greater variety of interests. The best structure for such a program is at present unclear.

A congressional hearing could be held to identify the main issues in establishing an animal germplasm

11 A thorough review of the National Plant Germplasm System undertaken by the National Research Council's Board on Agriculture found the system badly in need of extensive reforms. The recommendations include: development of clear NPGS goals and policies; development of a structure and organization to provide for national coordination and management of collections as national resources; increased NPGS investment in regenerating seed accessions, with extra attention to special collections; expansion of the National Seed Storage Laboratory, which is antiquated and insufficient to meet the needs of the national system; establishment of sites for maintenance of germplasm that requires short day-lengths or arid environments; taking a proactive role in long-term planning and policy development for broader collections that encompass a wider range of biological diversity; taking a more active role in developing U.S. policies that guide relations with international agencies; and NPGS cooperation with other nations' germplasm conservation programs [National Research Council, ***Managing Global Genetic Resources: The U.S. National Plant Germplasm System*** (Washington, DC: National Academy Press, 1991)].

program and to discuss alternative structures and scope of such a program.

Coordination of international efforts is also needed to preserve the diversity of agriculturally important animals. Some efforts have already been made, and the concept of an international program is gaining support. *Congress could encourage the establishment of an International Board for Animal Genetic Resources (IBAGR). This* program could parallel the International Board for Plant Genetic Resources (IBPGR). An IBAGR could set standards and coordinate the exchange and storage of germplasm between countries and address related issues such as quarantine regulations. It could foster onsite management of genetic resources for both minor and major breeds.

Another major gap is protection of U.S. ecosystem diversity. Numerous types of ecosystems, such as tall grass prairie, are not included in the Federal public lands system. *Congress could direct Federal land-managing agencies to include representative areas of major ecosystems in protected areas.*

One vehicle for this is the Research Natural Area (RNA) system. Since 1927, the RNA system, with the cooperation of multiple Federal agencies and private groups, has developed the most comprehensive coverage of natural ecosystem types in the United States. RNAs, however, are small scale and are mainly established on land already in public ownership. Therefore, the RNA system may not be able to cover the major ecosystems without some additional mechanism to acquire land not already in the Federal domain, possibly through land exchanges. Nevertheless, *Congress could recognize the RNA system as a mechanism and direct agencies to work toward filling the program gaps.*

Enhance the Knowledge Base

Developing effective strategies to maintain diversity depends on knowing the components of biological systems and how they interact. Information on the status and trends in biological systems is also needed for public policy. The first step in developing such information is fundamental descriptions of the various component-species, communities, and ecosystems. Data can then be analyzed to determine how best to maintain biological diversity. More specifically, baseline data are needed for the following activities:

- assessing the abundance, condition, and distribution of species, communities, and ecosystems;
- disclosing changes that may be taking place;
- monitoring the effectiveness of resource management plans once they are implemented; and
- determining priorities for areas that merit special efforts to manage natural diversity that would benefit from protection, and that deserve particular attention to avoid biological disruption or to initiate mitigative actions.

To be effective and efficient, the acquisition, dissemination, and use of data must proceed within the context of defined objectives. For the most part, biological data used in diversity maintenance programs have been acquired without the direction of a coordinating goal. Not surprisingly, these data are widely scattered and generally incompatible. Geographical and taxonomical data gaps exist. Some taxonomic groups are ignored in field inventories, while others, particularly plants and animals with economic or recreational value, are monitored extensively. Finally, few data exist on the social, economic, and institutional pressures on biological diversity. Consequently, available data cannot be used easily in decisionmaking directed at maintaining biological diversity.

FINDING 5: Congress and other policymakers need improved information on biological diversity. Such information cannot be supplied without improvements in data collection, maintenance, and synthesis.

Policymakers need comprehensive information on the ramifications and scope of diversity loss. Information provided by the scientific community should be a basis for resource policy and management decisions. To serve in the context of public policy, data should satisfy four criteria:

1. The data must be of *high quality; they* must meet accepted standards of objectivity, completeness, reproducibility, and accuracy.
2. The data must have *value; they* must address a worthwhile problem.
3. The data must be *applicable; they* must be useful to decisionmalcers responsible for making policy.
4. The data must be *legitimate; they* must carry a widely accepted presumption of accuracy and authority.

Much information is already available but not in an assimilated form useful to decisionmakers. Data on the status and trends of biological diversity are scattered among Federal, State, and foreign agencies and private organizations. Consolidation of these data is necessary to identify gaps, to provide a comprehensive understanding of the status of the Earth's biota, and especially to define priorities for action.

Option 5.1: Establish a small clearinghouse for data on biological diversity.

The purpose of a clearinghouse would be to coordinate data collection, synthesis, and dissemination efforts. It could serve government agencies, private organizations, corporations, and individuals. The clearinghouse could perform the following functions:

- survey and catalog existing Federal, State, private, and international databases on biological resources;
- evaluate the quality of databases;
- provide small grants and personnel support services to strengthen existing databases; and
- publish annual reports on the status and needs of the biological data system.

Success in these endeavors would accelerate progress toward several objectives:

1. setting of priorities for conservation action;
2. monitoring trends;
3. developing an alert system for adverse trends;
4. identifying gaps and reviewing needs to fill them;
5. facilitating development of environmental impact assessments; and
6. evaluating options, actions, and successes and failures.

As a data-coordinating body, the clearinghouse could guide efforts to collect data on biological diversity, which will provide a comprehensive perspective that Federal agencies cannot supply because of their varied mandates. Access to previously inaccessible data would be facilitated, which should reduce duplication of effort. By evaluating the quality of information, the clearinghouse could help eliminate a general distrust among users of other databases. Access to a diversity of databases means no standardized system is forced on data users, which has been a formidable obstacle to database integration and use.

The clearinghouse *would not necessarily* maintain its own primary database. Commercial databases in the public domain could be included in the system, and proprietary and other limited-access databases could be reviewed regularly, with permission. Database enhancements to cover gaps could be funded by small grants. The clearinghouse's information systems could be made available through a library service and special searches. It could charge appropriate fees for all its services.

The same clearinghouse could assess information on biological diversity in international databases. It could provide a small amount of financial and personnel aid to help international organizations improve their databases. In addition, it could work with development assistance agencies to support the participation of other countries' national databases in such international and regional networks as the International Union for the Conservation of Nature and Natural Resources' Conservation Monitoring Center, the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere Program (MAB), and The Nature Conservancy International.

Possible objections to such a clearinghouse include the following: 1) lack of a unifom system of data collection for the United States would hinder national data analysis and use, and 2) evaluating the quality of other agencies' databases would be politically sensitive. Questions such as the size, administrative structure, and cost of a clearinghouse program must be answered as well. Because it would not maintain its own primary database, however, such a clearinghouse would not need to be a large-scale operation.

Option 5.2: Provide funding to enhance the existing network of natural heritage conservation data centers.

A number of state governments, aided by The Nature Conservancy (TNC), have already established a network of Natural Heritage Data Centers in many States and in some foreign countries. These centers collect and organize biological data specifically for diversity conservation. All centers use a standardized format to collect and synthesize data. The result has been a vehicle to exchange and to aggregate information about what is happening to

biological resources at State and local levels and, more recently, around the Nation and across the Western Hemisphere.

Funding for these data centers comes from a combination of Federal, State, and private (including corporate) sources. Progress has been limited, however, by the amount of available funds. *Congress could enhance these efforts by providing a consistent source of addition al funding. By* increasing support for the Federal-State-private partnership, the action by Congress could reinforce the application of standard methods, enhance interagency compatibility, improve the efficiency of biological data collection and management, and facilitate the free exchange of useful information. Moreover, the partnership could accelerate the rate at which data centers spread to the remaining States and nations.

An appropriation of $10 million per year, for example, could be divided among several data center functions: supporting central office activities in research, development, documentation, and training; conducting taxonomic work; and matching grants from States and other participants. One source of funding could be the Land and Water Conservation Fund. Although this fund is used mainly for land acquisition, it could also support preacquisition activities such as identification of lands to be acquired. Data centers are key to such activities.

This option does not necessarily replace the need for an information clearinghouse because diverse databases and information systems will continue to operate. The two options could be complementary. Some clearinghouse functions might be handled by TNC, but others, such as facilitating improvement of and access to data sources, could be best handled by a separate entity that functions much like a library.

Support International Initiative to Maintain Biological Diversity

Most biological resources belong to individual nations. However, many benefits from diversity accrue internationally. American agriculture, for example, depends on foreign sources for genetic diversity to keep ahead of constantly evolving pests and pathogens. And many bird populations important to controlling pests in the United States overwinter in the forests of Latin America.

Solutions to problems that cause diversity loss must be implemented locally, but many of these will be effective only if supported by international political and technical cooperation. Examples of such problems include the international trade in rare wildlife, the greenhouse effect of certain gases on the climate, the effects of acid rain on freshwater lakes and forests, and damage to oceans by pollution and overfishing. The United States has the political prestige needed to initiate international cooperation, and it leads the world in much of the technical expertise needed, such as fundamental biology and information processing. Thus, the United States has both motive and ability to participate and to provide leadership in international conservation efforts.

The United States historically has played a leading role in promoting international conservation initiatives, and precedence exists for extending this leadership to an international or global approach for conserving biological diversity. A variety of international conventions and multilateral programs already specifies biological diversity as an aspect of broader conservation objectives (e.g., biosphere reserve program). Such internationally recognized obligations can be important policy tools in concert with technical, administrative, and financial measures to encourage programs for conserving diversity. Obligations confirmed by international conventions provide conservation authorities with the justification frequently needed to strengthen their national programs.

FINDING 6: The United States has begun to abdicate leadership in international conservation efforts, with the result that international initiatives are weakened or stalled in the tropical regions where diversity losses are most severe. Renewed U.S. commitment could accelerate the pace of international achievements in conservation.

The United States has been a model and an active leader in international conservation activity. The movement toward establishment of national parks worldwide grew out of the United States. In the early 1970s, the United States was a leader in international environmental and resource deliberations, notably in the 1972 UN-sponsored Stockholm Conference on the Human Environment. U.S. leadership, for example, played an important role in establishing the United Nations Environment Programme (UNEP), and in securing the Convention on International

Trade in Endangered Species of Wild Fauna and Flora (CITES) and the World Heritage Convention, all important foundations of current international efforts to support maintenance of biological diversity.

However, U.S. support for these kinds of initiatives has declined. The retrenchment in support reflects austerity measures as well as dissatisfaction with the performance of specific international organizations. Effective international projects, such as UNESCO's Man and the Biosphere Program, have suffered by association.

U.S. support of international conservation efforts is pivotal in that the United States has greater resources and stronger technical abilities than most other countries to address the complex issue of diversity loss. Without greater initiative and access to resources, many countries will be unable to arrest loss of diversity within their borders. Under existing conditions, countries that harbor the greatest diversity are expected to devote a large part of their national resources to address the problem, even though benefits commonly extend beyond their countries. It would seem equitable for those countries that benefit, including the United States, to share more fully in efforts to conserve diversity in countries otherwise unable to do so.

Option 6.1: Sustain or increase support of international organizations and conventions.

International conservation initiatives are important tools for long-term conservation of biological diversity. Yet, existing international agreements are often poorly implemented because of lack of adequate administrative machinery (e.g., adequately funded and staffed secretariats), lack of financial support for on-the-ground programs (e.g., equipment, training, and staff, and lack of reciprocal obligations that could serve as incentives to comply.

An exception is CITES, which has mechanisms to facilitate reciprocal trade controls and a technical secretariat. The existence of this machinery in large part accounts for the relative success of this convention. The United States has been globally influential in supporting CITES and has reinforced it through national legislation that prohibits import into the United States of wildlife taken or exported in violation of another country's laws. The amendment to the Lacey Act of 1900 (Public Law 97-79) in 1981 backs efforts of other nations seeking to conserve their wildlife resources. This law has been a powerful tool for wildlife conservation throughout the world because the United States is a major importer of wildlife specimens and products.

U.S. contributions to international conservation programs have been diminishing recently. The appropriation cycle for funding such programs has been an annual tug-of-war between Congress and the Administration. The budget of the World Heritage Convention in 1985 was $824,000. The United States, one of the major forces behind the Convention's founding, usually contributes at least one-fourth of the budget. U.S. contributions averaged $300,000 in fiscal years 1979 to 1982. From fiscal year 1982 to 1984, the United States made no contributions, but contributed $238,903 in fiscal year 1985. In fiscal year 1986, $250,000 had been appropriated, but the amount was cut to $239,000 under Gramm-Rudman-Hollings Balanced Budget and Emergency Deficit Control Act.

Congress could maintain or increase U.S. support of international organizations and programs in several ways. *Congress could ensure that these organizations receive adequate annual appropriations and could conduct oversight hearings to encourage the Administration to carry out the intent of Congress.*

One possible drawback associated with contributions to international intergovernmental organizations is their lack of accountability. Compared to



Photo credit: Walter E. Patiam, Office of Ttino/ogy Assessment

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established to reduce or eliminate trade in products derived from endangered species. Products such as the elephant ivory shown here, however, continue to be illegally moved in international trade.

bilateral assistance channels, the United States has little control over how or to whom intergovernmental organizations direct their resources. The consequence is that U.S. funds go to countries that are unfriendly or even adversarial to the United States and its policies.

It should be recognized, however, that many international activities specific to maintenance of biological diversity, especially activities of UNEP, UNESCO-MAB, and IBPGR, operate largely within scientific channels, which tends to reduce the political overtones inherent in intergovernmental organizations. Also, objectivity can be enhanced in programs willing to establish protocols. For example, establishing criteria to determine which areas qualify for biosphere reserve status or which unique areas warrant (natural) World Heritage status provides objectivity in directing resources.

Congress could also encourage or direct Federal agencies to assign technical personnel to international organization or to the secretariats of the various conventions. This option could be difficult to implement without legislating special allowances for agency personnel ceilings and budgets. Otherwise, agencies will be reluctant to assign personnel overseas in light of a shrinking Federal work force and budget.

Option 6.2: Continue to direct U.S. directors of multilateral development banks (MDBs) to do the following: 1) press for more specific and systematic MDB efforts to promote sound environmental and resource policies akin to the World Bank's wildland policy, 2) work to make projects consistent with international and recipient country environmental policies and regulations, and 3) seek to involve recipient country environmental officials and nongovernmental organizations in project formulation processes.

A significant part of all international development assistance efforts is funded by the World Bank and regional MDBs. Thus, these organizations are uniquely situated to influence environmental aspects of development, including the maintenance of biological diversity. In fact, the MDBs' priorities and policies can be the single most important influence on the development model adopted by developing countries. MDB agricultural, rural development, and energy programs all have profound effects on biological resources in developing countries.

The World Bank promulgated a new policy in 1986 on the treatment of wildlands in development projects. The bank recognizes that although further conversion of some natural land and water areas to more intensive uses will be necessary to meet development objectives, other pristine areas may yield benefits to present and future generations if maintained in their natural state. These are areas that, for example, may provide important environmental services or essential habitats to endangered species. To prevent the loss of these wildland values, the policy specifies that the Bank will normally decline to finance projects in these areas and instead prefer projects on already converted lands. Conversion of less important wildlands must be justified and compensated by financing the preservation of an ecologically similar area in a national park or nature reserve, or by some other mitigative measures. The policy provides systematic guidance and criteria for deciding which wildlands are in need of protection, which projects may need wildland measures, and what types of wildland measures should be provided.

In 1980, the World Bank, Inter-American Development Bank, Asian Development Bank, and six other multilateral signed a "Declaration of Environmental Policies and Procedures Relating to Economic Development,' and formed the Committee on International Development Institutions on the Environment (CIDIE), under the auspices of the United Nations Environment Programme. The agencies agreed to systematic environmental analysis of activities funded for environmental programs and projects. However, a subsequent study found these policy statements by the MDBs were not effectively translated into action. Criticisms of how well MDBs implement environmental policies remain strong. And it is too soon to determine the effectiveness of the World Bank's wildland policy.

The United States is limited in its ability to effect change at MDBs because the banks are international institutions run collectively by member nations. Since the United States is a large contributor, however, it does have considerable influence on bank policies, which are determined by boards of directors.

The primary way Congress affects policies of these banks is by requesting that the U.S. executive directors-who are responsible to the Secretary of the Treasury-carry out congressionally approved

policies. These requests may be made at oversight hearings or in the language of appropriation legislation. For instance, the 1986 House Committee on Appropriations Report stated guidelines for the U.S. executive directors (Sec. 539), which included the addition of relevant staff, development of management plans, and commitment to increase the proportion of programs supporting environmentally beneficial projects. To continue this guidance, *Congress could require the U.S. executive directors of MDBs to encourage adoption of a policy similar to the World Bank's wildlands policy statement.*

FINDING 7: Constraints on international exchange of genetic resources could jeopardize future agricultural production and progress in biotechnologies. Such constraints are becoming more likely because developing countries with sovereignty over most such resources believe the industrial nations have benefited at their expense. Debates on the issue could benefit from a more informed and less impassioned approach.

All countries benefit from the exchange of genetic resources. Many of the major crops currently grown in various countries have originated elsewhere. Coffee, for example, is native to the highlands of Ethiopia. Yet, today, it represents an important source of income for farmers in other parts of Africa, Asia, and Latin America. Maize, originally from Central America, is grown as a staple crop in North America and Africa. Countries continue to depend on access to germplasm from outside their borders to maintain or enhance agricultural productivity. Political and economic considerations, however, are now prompting national governments to restrict access to their germplasm. Behind these efforts is an implicit desire by some countries to obtain greater compensation for the genetic resources currently made freely available.

The International Board for Plant Genetic Resources (IBPGR) is the main international institution dealing with the offsite conservation of plant genetic diversity. Established in 1974, it promotes establishment of national programs and regional centers for the conservation of plant germplasm. It has provided training facilities, carried out research in techniques of plant germplasm conservation, supported numerous collection missions, and provided limited financial assistance for conservation facilities. However, it does not operate any germplasm storage facilities itself.



Photo credit: Alison L. Hess, Office of Technology Assessment

Exchange of genetic resources in the form of crops historically has been an integral component of exploration and trade. The infamous "Mutiny on the Bounty" took place on a ship carrying breadfruit seedlings from the Pacific to Caribbean islands. Although the Bounty never completed its journey, breadfruit has become a staple food on some Caribbean islands.

Due in part to the success of IBPGR in focusing attention on the need to conserve genetic diversity, the issue of germplasm exchange has become embroiled in political controversy. Some critics regard the IBPGR as implicitly working for agribusiness interests of industrial nations. Central to the issue is a perception on the part of many developing countries that they have been freely giving genetic resources to industrial nations which, in turn, have profited at their expense.

This controversy led the United Nations Food and Agricultural Organization (FAO) to sponsor an International Undertaking on Plant Genetic Resources. The undertaking proposed an international germplasm conservation network under the auspices of FAO. It declared that each nation has a duty to make all plant genetic materials-including advanced breeding materials-freely available. IBPGR

was to continue its current work, but it would be monitored by FAO.

FAO then established the Commission on Plant Genetic Resources to review progress in germplasm conservation. The commission held its first meeting in March 1985, with the United States present only as an observer. Much of the discussion focused on the concerns expressed in the undertaking and on onsite conservation.

The continuing controversy includes charges that the current international system enables countries to restrict access to germplasm in international collections for political and economic reasons. Also of concern to some parties is the impact of plant patenting legislation.

Current charges and arguments in the FAO forum tend to oversimplify the complexity of how germplasm is incorporated into plant varieties and to distort the actual nature of genetic exchange between and among industrial and developing countries. Restrictions on export of germplasm, for example, appear to be more common for developing countries. Nevertheless, the perception of inequity in the current situation is real, and it could result in increasing national restrictions on access to and export of germplasm. Further, the issue of control over genetic resources could become a significant stumbling block to establishing international commitment and cooperation in the maintenance of overall biological diversity.

Option 7.1: Closely examine the actions available to the United States regarding the issue of international exchange of genetic resources.

Efforts to address the conservation and exchange of plant genetic resources in the FAO forum have been controversial. It is not yet apparent how the United States should act in this regard. Congress could give increased attention to determining what options are available.

One possible action is for Congress to request that an independent organization, such as the National Academy of Sciences, study this issue. In fact, NAS has already indicated interest in investigating this as a part of its current 3-year study of global genetic resources. Such a study could draw on other agencies and individuals with interest and expertise in this area to define several general actions the United States might take in regard to international exchange of genetic resources and the consequences associated with it.

Another option is to favor the status quo, ignoring the criticisms and avoiding the risk that new political actions might disrupt effective scientific working arrangements. A practical international flow of germplasm is likely to continue in the future, with or without the formal international arrangements envisioned by the FAO undertaking. In time, the political issues may be resolved equitably without pushing nations into conflicts over breeders' rights or access to genetic materials.

Another possibility would be for the United States to associate with the FAO Commission on Plant Genetic Resources. U.S. influence might strengthen the international commitment to free flow of germplasm and reduce the risk that germplasm will increasingly be withheld for political or economic reasons.

Unless Congress chooses to restrict plant breeders' rights in the United States, the U.S. Government will be unable to join the undertaking without major reservations. Such a change in domestic law seems politically unlikely, given domestic benefits provided by plant breeders' rights and the effective lobbying efforts of the seed industry. However, the United States could consider renegotiating the FAO undertaking to require a commitment to grant global access to genetic resources-with appropriate exceptions for certain privately held materials-within the context of an internationally supported commitment to help countries conserve and develop their genetic resources. Parallel agreements also might be developed for domestic animal, marine, and microbial resources. Such agreements could also define national and international obligations to collect and conserve the germplasm that is being displaced by new varieties or by changing patterns of agricultural developments.

Finally, U.S. representatives could consider promoting a discussion of genetic resource exchanges outside formal channels in an effort to separate the technical issues from emotional ones. The Keystone Center, an environmental mediation organization, is exploring the possibility of conducting a policy dialog on this topic in the near future.

Option 7.2: Affirm the U.S. commitment to the free flow of germplasm through an amendment to the Export Administration Act.

Specific allegations have been made that the United States has restricted the access to germplasm in national collections (at the National Plant Germplasm System) for political reasons. The government, however, maintains it adheres to the principles of free exchange.

To reinforce recent executive affiliations of the free flow of germplasm, *Congress could exempt the export of germplasm contained in national collections from Export Administration Act restrictions or political embargoes imposed for other reasons.* Comparable provisions are already included in this act with respect to medicine and medical supplies (50 U.S.C. app. sec. 2405 (g), as amended by Public Law 99-64, July 12, 1985). Because this germplasm is already accessible through existing mechanisms, such a provision would only reaffirm the U.S. position and remove from the current debate the allegations of U.S. restrictions of access to germplasm.

On the other hand, the process of amending the act may generate support for restricting germplasm by excluding certain countries from such an exemption. Restricting access in such a manner would likely lead to an international situation counter to U.S. interests. In such a case, no action would be preferable to an amendment.

Address Loss of Biological Diversity in Developing Counties

The United States has a stake in promoting the maintenance of biological diversity in developing countries. Many of these nations are in tropical regions where biological systems are highly diverse, where pressures that degrade diversity are generally most pronounced, and where the capacity to forestall a reduction in diversity is least well developed. The rationale for assisting developing countries rests on: 1) recognition of the substantial existing and potential benefits of maintaining a diversity of plants, animals, and microbes; 2) evidence that degradation of specific ecosystems is undermining the potential for economic development in a number of regions; and 3) esthetic and ethical motivations to avoid irreversible loss of unique life forms.

The U.S. Congress, recognizing these interests, passed Section 119 of the Foreign Assistance Act of 1983, specifying conservation of biological diversity as a specific objective of U.S. development assistance. The U.S. Agency for International Development (AID), as the principaI agency providing development assistance, was given a mandate to implement this policy, which reads in part:



Photo credit: Alison L. Hess, 0ffic8 of T=hnology Assessment

The U.S. Agency for International Development was directed by Congress to provide support for establishing and maintaining wildlife sanctuaries, reserves, and parks in tropical developing countries, to protect the habitat of such species as East Africa's Grants Gazelle.

> In order to preseme biological diversity, the President is authorized to furnish assistance to countries in protecting and maintaining wildlife habitats and in developing sound wildlife management and plant conservation programs. Special effort should be taken to establish and maintain wildlife sanctuaries, reserves, and parks; to enact and enforce antipoaching measures; and to identify, study, and catalog animal and plant species, especially in tropical environments.

A review of AID initiatives since 1983 suggests that despite the formulation of a number of policy documents, the agency lacks a strong commitment to implementing the specific types of projects identified in Section 119. This lack of commitment is due to several factors, including: 1) a belief that the agency is already addressing biological diversity to the extent it should, 2) reduced levels of budgets and staff to initiate projects, and 3) an inadequate number of trained personnel to address conservation concerns generally.

Several questions arise in relation to the capacity and the appropriateness of U.S. commitments to support diversity conservation efforts through bilateral development assistance. First, it is uncle~ whether Section 119, as the principal legislation dealing with concerns over diversity loss outside the United States, defines U.S. interests too narrowly.

Second, it is uncertain how Section 119 relates to the principal goals of foreign assistance, as specified in Section 101. Finally, questions remain concerning the commitment of resources and personnel to address U.S. interests in maintaining diversity in developing countries.

FINDING 8: Existing legislation may be inadequate and inappropriate to address U.S. interests in maintaining **biological diversity in developing countries.**

Maintaining **diversity will depend primarily** on onsite maintenance. The ''special effort' initiatives identified in Section 119 are important components of a comprehensive program. What is not clear, however, is whether the emphasis is appropriate within the context of U.S. bilateral development assistance. That is, establishing protected areas and supporting anti-poaching measures can have adverse impacts on populations that derive benefits from exploiting resources within a designated area. These populations are characteristically among the ''poorest majority'' intended to be the principal beneficiaries of U.S. development assistance (Sec. 101). However, demands of local populations (e.g., for fuelwood or agricultural land) may threaten diversity and even the sustainability of the resource base on which they depend. It does, however, raise questions on the appropriateness of supporting activities that could place increased stress on these populations.

Second, existing legislation identifies concern over diversity loss separately from conversion of tropical forests and degradation of environment and natural resources (Sec. 118 and 117, respectively). Clearly, these concerns are interrelated, although not synonymous. It is questionable whether such a distinction is appropriate within the context of development assistance legislation. An argument can be made that U.S. development assistance should approach diversity maintenance within the context of conservation-that is, as a wise use of natural resources, as elaborated in the World Conservation Strategy. In doing so, the objectives of diversity maintenance and development interests could be made more compatible.

Finally, although Section 119 speaks of biological diversity, the thrust of the legislation addresses a narrower set of concerns-that of species extinction. While certainly a prominent concern, and perhaps even the central motivation behind the legislation, it fails to address the broader set of U.S. concerns over diversity loss in developing countries. As noted earlier, a focus on unique populations would be a more appropriate, though more problematic, approach. This is particularly important with regard to preserving genetic resources of potential benefit to agriculture or industry, which is the most strongly argued rationale for conserving biological diversity. Existing legislation does not specifically identi~ these interests.

Option 8.1: Restructure existing sections of the Foreign Assistance Act to reflect the fill scope of U.S. interests in maintaining biological diversity in developing countries.

The U.S. Foreign Assistance Act (FAA) comes up for reauthorization in 1987. Major restructuring of the act is already being considered. Revamping could provide an opportunity to recast certain provisions of the legislation to better account for U.S. interests in maintaining diversity in developing countries.

Providing for conservation of natural resources and the environment in general, and of biological diversity and tropical forests in particular, are important considerations in a restructuring of FAA. Less clear, however, is whether the language and disaggregation of these interests is appropriate in the context of bilateral development assistance.

One specific consideration could be to resolve potential conflicts of interest that exist in the language of Section 119—that of emphasizing the need to establish protected areas and poaching controls without specific reference to impacts on indigenous populations. *Congress could correct this potential conflict by adding language to Section 119 such as, "Support for biological diversity projects should be consistent with the interests, particular needs, and participation of local populations.'* It **is** widely recognized that the viability of protected areas is largely contingent on these provisions. Adding such language would thus provide greater consistency within the objectives of FAA as well as specify criteria that heighten chances of project success.

In addition, *Congress could recast the language of existing legislation to provide a fuller accounting of U.S. interests in maintaining diversity in developing countries.* Such changes could expand *from* a

focus on endangered species to the loss of biological systems, including ecosystems and genetic resources. Such an effort might also emphasize practical aspects of conservation initiatives of particular interest to developing countries and stress the goal of promoting ability and initiatives of the countries themselves.

Finally, *Congress could combine those sections of FAA that deal with natural resources and environmental issues to reflect the interrelatedness of these amendments.* Provisions could be made to account for specific concerns over species extinctions currently emphasized in Section 119. But approaches and concerns reflected in these amendments are probably best considered together. Provision of funding within such a restructuring would also be important.

FINDING 9: AID could benefit from additional strategic planning and conservation expertise in promoting biological diversity projects.

Congress has already taken steps to earmark finds for biological diversity projects within AID's budget. The existing mechanisms within the agency to identify and promote diversity projects are not well established, however. Because funding is minimal, it is all the more important to devise a strategy that allows priority initiatives to be defined.

Environmental expertise within AID is slim. In recent years, in-house expertise in this area has declined, and that which does exist has been severely overextended. Addressing biological diversity will, therefore, require both increasing the number of AID staff with environmental training and an increased reliance on expertise outside AID, in other government agencies and in the private sector. AID has already taken steps to cultivate this environmental expertise, but further actions could be taken.

Option 9.1: Direct AID to adopt a more strategic approach in promoting initiatives for maintenance of biological diversity .12

The U.S. Strategy on the Conservation of Biological Diversity: An Interagency Task Force Report to Congress was delivered to Congress in February 1985, in response to provisions in Section 119. A general criticism of the document was that although it contained 67 recommendations, it lacked any sense of priority or indication of funding sources to undertake these recommendations. In an attempt to apply the recommendations to specific agency programs, AID drafted an *Action Plan on Conserving Biological Diversity in Developing Countries* (January 1986). Comments received from AID overseas suggest that problems exist in translating the general principles and recommendations of an agency plan into specific initiatives at the country level.

A more refined approach to addressing diversity interests within the agency may be required. Such an approach would seek to incorporate biological diversity concerns into AID development activities at different levels of the agency, ranging from general policy documents at the agency level to

12 AID announced a new Environment Initiative in June 1990, with the expressed intent of linking environmental activities to development Concerns, to be followed by a Strategy Statement focusing the Agency's environmental and natural resource efforts, and an Action Plan to provide operational guidelines. In its initial investigations, each extant regional bureau identified loss of biodiversity, conversion of tropical forests, and land degradation as primary environmental concerns. AID currently is developing the new Environmental Strategy, expected to be released shortly, that will establish a formal structure under which all regional bureau strategies will be conducted [U.S. Agency for International Development, "The Environment Initiative Progress Update--April 1991," Washington, DC, April 1991].

AID established the Conservation of Biological Diversity Project (CBD) in September 1988 as a direct response to congressional mandates to bring biodiversity conservation into its projects (sections 118 and 119). The goal of CBD is to provide support to AID-supported countries to improve their capacity to understand and respond to biodiversity conservation issues. In the 3 years since its inception, core funding for the CBD has risen from $9.8 million to $20 million, with a current request to raise the ceiling yet again to $30 million to be expended over the 10 year life of the project (regional bureaus and country missions may provide additional funding to the CBD to carry out projects identified for their regions).

The CBD has two components at present: a Cooperative Agreement with the World Wildlife Fund which established a consortium with the Nature Conservancy and the World Resources Institute and which in turn established the Biodiversity Support program, and an Interagency Agreement with the National Science Foundation made subsequent to a congressional earmark for AID to fund NSF biodiversity research programs. These components provide support for research; technical assistance; training; collection, evaluation, and dissemination of information establishment of networks that facilitate access by developing country institutions and scientists to financial and technical resources; and small grants to host country scientists.

The Biodiversity Support Program currently employs 13 people who are involved in approximately 120 activities in 60 AID-supported countries. The AID/NSF Interagency Agreement directs funding to strengthen programs and facilities for biodiversity research and education, and creates another venue for collaborative working relationships between U.S. and foreign scientists. For fiscal years 1991 and 1992, at least $7 million was devoted by both agencies to support 33 biodiversity projects worldwide (the $2.5 million from AID is devoted solely to projects in AID-supported countries). [Dr. Sy Sohmer, Senior Biodiversity Adviser, Office of Environment and Natural Resources, Bureau for Research and Development U.S. Agency for International Development personal communication, Washington, DC, Apr. 17, 1992].

more strategic efforts at the regional bureau and mission levels.

At least two efforts could be considered at the agency level. First, *Congress could direct AID to prepare a policy determination (PD) on biological diversity.* **A** PD would serve as a general statement that maintaining diversity is an explicit objective of the agency. In developing a PD, AID should review provisions contained in the recent World Bank wildlands policy statement.

Existence of a PD could mean that consideration of diversity concerns would, where appropriate, become an integral part of sectoral programming and project design. Further, it would require that projects be reviewed and evaluated by the Bureau of program and Policy Coordination for consistency with the objectives of the PD. Because of the increase in bureaucratic provisions this would create, the formulation of a PD on diversity probably would not be well received within AID.

A second effort is to establish a centrally funded project within AID's Bureau of Science and Technology. AID has already developed a concept paper along these lines as a prelude to a more concrete project identification document. As conceived, the concept paper examines the possibility of establishing a biological diversity project. One major benefit of such a project would be the establishment of a focal point for coordinating funding and technical assistance on biological diversity. The Science and Technology Bureau's emphasis on technical assistance, research, training, and institutional development would make it the appropriate bureau for such a program. A constraint to this approach is that biological diversity projects may continue to be separate rather than an integral part of development programs.

The three regional bureaus of AID (i.e., Africa, Asia and Near East, and Latin America and the Caribbean) could also prepare documents that identify important biological diversity initiatives in their regions.[13] The Asia and Near **East Bureau, in fact,** has already prepared such a document that could be used in highlighting regional priorities. A reluctance to direct scarce funds to diversity projects, at the expense of more traditional development projects, has limited the utility of the document to date. Nevertheless, the development of such reports for each regional bureau is considered an effective way to identify priorities for existing diversity projects, especially given the earmarking of funds.

The most important focus of biological diversity strategies is at the mission level, where projects are implemented. Congress has already mandated that Country Development Strategy Statements and other country-level documents prepared by AID address diversity concerns. Most missions, however, lack the expertise or adequate access to expertise needed to address this provision of Section 119 as amended.

Option 9.2: Direct AID to acquire increased conservation expertise in support of biological diversity initiatives.[14]

The ability of AID to promote biological diversity in developing countries is seriously undermined by its lack of personnel trained in environmental sciences. While true at the agency headquarters, the problem is particularly acute in its overseas missions. Although AID designates an environmental officer at each mission, the person usually has little professional experience or training in the area. Often environmental duties are combined with numerous other duties; few AID personnel are full-time environmental officers. Under these circumstances, it is difficult to envision how AID can effectively promote biological diversity maintenance.

Congress could direct AID to recruit and hire additional personnel with environmental science backgrounds or, at a minimum, provide increased training for existing staff. The near-term prospects

[13] As established in the newly reorganized AID, five regional bureaus now exist: Bureau for Africa, Bureau for Asia, Bureau fOr Europe, Bureau for Latin America and the Caribbean, and Bureau for Near East. In addition, based on the break-up of the former Soviet Union, a Task Force for the Newly Independent States has been created. Each of these bureaus will be involved in development of the Environment Strategy and Action Plan.

[14] AID activities in support of conservation of biodiversity have burgeoned since publication of the OTA assessment in 1987, Funding for biodiversity conservation efforts rose to $72 million by 1991 [Dr. Sy Sohmer, Senior Biodiversity Adviser, Office of Environment and Natural Resources, Bureau for Research and Development, U.S. Agency for International Development, personal communication, Washington, DC, Apr. 17, 1992]. At the same time, however, the number of direct hire environmental specialists has not grown commensurately. Responding in part to congressional directives, AID has stated explicit intentions to improve its environmental expertise by increasing the number of contracted environmental and natural resource advisors, and through a 5-year in- service environmental training program [U.S. House of Representatives, Committee on Foreign Affairs, 'Recent Environmental Activities of the Agency for International Development, " Hearing before the Subcommittee on Human Rights and International Organizations, Committee on Foreign Affairs, U.S. House of Representatives, Washington, DC, Sept. 26, 1990].

for AID, however, point to a reduction in an already overworked staff. It seems unlikely, therefore, that significant in-house conservation expertise will be developed. Consequently, addressing biological diversity within AID will depend on providing access to conservation expertise within other government agencies and in the private sector. Even drawing on outside expertise, AID will need some increase in environmental officers to manage and coordinate projects.

AID already draws on other government agencies to participate in projects supporting biological diversity maintenance. Mechanisms such as Participating Agency Service Agreements (PASA) and Resource Services Support Agreements (RSSA) allow interagency exchanges of experts and services. AID currently has a RSSA with Fish and Wildlife Service for the services of a technical advisor to handle biological diversity issues. These mechanisms could be used to facilitate further access to conservation experts in other government agencies.

A biological diversity program could be established within the existing Forestry Support Program, for example. The Forestry Support program is an RSSA between AID and the U.S. Department of Agriculture (USDA) to provide technical assistance to AID in the area of forestry and natural resources. A diversity program would likely be an RSSA between AID, the Department of the Interior, and USDA. Such a program would provide AID missions with access to conservation expertise within the Department of the Interior, the USDA, and through a roster of consultants.

A constraint to the RSSA and PASA is agency personnel ceilings and the limited number of personnel with international experience. In light of a reduction of the Federal work force, agencies maybe reluctant to devote their staff to nonagency projects. Although some Federal programs have been successfully used in supporting AID projects, expertise within the private sector will also be needed to address AID's requirements.

The Peace Corps is also seen as having special potential to support biological diversity projects. Cooperative agreements with the National Park Service, Fish and Wildlife Service, the U.S. Man in the Biosphere Program, and World Wildlife Fund/ U.S. have increased the Peace Corps' capacity and access to talent and training in this area, Another area of potential collaboration is between the Peace Corps and the Smithsonian Institution, especially given the Smithsonian's newly established Biological Diversity Program. Precedence exists for such a cooperative relationship, in the form of the Smithsonian-Peace Corps Environmental Program, which was terminated in the late 1970s. With the emergence of special interests in diversity maintenance, *Congress could direct both agencies to investigate reestablishing a similar initiative focused on biological diversity projects.*

Section 119 of FAA states:

> whenever feasible, the objectives of this section shall be accomplished through projects managed by appropriate private and voluntary organizations, or international, regional, or national nongovernmental organizations which are active in the region or country where the project is located.

A number of nongovernmental organizations (NGOs) are already working with AID to develop capacity to maintain diversity in developing countries. These include important initiatives in the areas of conservation data centers, of supporting development of national conservation strategies, and of implementing field projects. AID is also using a private NGO to maintain a listing of environmental management experts. Such partnership could continue to be encouraged by Congress through oversight hearings, for instance. Encouraging joint public-private initiatives through matching grants should also be stressed.

FINDING 10: A major constraint to developing and implementing diversity-conserving projects in developing countries is the shortage of funds. Present funding levels are insufficient to address the scope of the problem adequately.

Recently passed legislation earmarked $2.5 million of AID's 1987 funds for biological diversity projects. Given that this amount is intended to be used to address diversity loss over three continents and is guaranteed for only 1 year, its adequacy can be questioned. Faced with prospects of further cuts in an already reduced foreign assistance budget and a shift in the composition of this budget to proportionally less development and food aid in favor of military aid and economic support finds, it is difficult to see where further funding for diversity maintenance could be derived.

Option 10.1: Establish anew account within the AID budget to support biological diversity initiatives identified in the Foreign Assistance Act.

Sections 117, 118, and 119 of FAA all define congressional interest in conservation as an integral aspect of development. With the exception of the 1987 earmarking of funds for biological diversity, no formal funding source has been attached to these sections. The result is that support for conservation initiatives generally has been weak, Support has been further eroded recently because those functional accounts used for conservation projects—Agriculture, Rural Development, and Nutrition; and Energy, Private Voluntary Organization, and Selected Development Activities-have received disproportionate funding cuts.

Congress could define its support for the importance of conservation to development by establishing a separate fund, perhaps called an Environment and Natural Resources Account, that could be used by AID to support diversity maintenance activities. Concerns exist that functional accounts generally tend to reduce AID's flexibility, and consideration has even been given to eliminating them entirely. If established, however, an Environment and Natural Resources account could be used to define congressional concerns in this area. Specific earmarking for biological diversity could be considered within this new functional account.

Option 10.2: Amend the Agricultural Trade Development and Assistance Act of 1954, specifying that funds from the Food for Peace Program (Public Law 480) could be used for projects that directly promote the conservation of biological diversity.

An existing source of funds for biological diversity projects is Public Law 480 Food for Peace program. Titles I and III make commodities available at confessional rates with long-term, low-interest financing for debts incurred. Recipient countries resell the U.S. commodities and are required by contract to apply part of the currency to self-help projects agreed on between the country and the AID mission. The country can eventually cancel some of its debt by applying equivalent funds to long-term development projects. Title II provides U.S. commodities to developing countries in cases of emergency or for nutrition and development programs. This Food for Work program has conducted reforestation and resource management projects in which laborers are paid with food and with wages generated from the resale of U.S. commodities. Hence, Public Law 480 funds are already being used to finance projects that promote diversity maintenance. *More could be done* if *Congress amends Public Law 480 specifying that funds could be used for diversity conservation projects.*

Other existing funding mechanisms could be redirected to include funding of diversity projects. In response to funding cuts at AID, conservation groups have proposed certain ways to provide money for biological diversity projects. One such mechanism is the use of economic support funds for additional development assistance programs. Though primarily used for other purposes, economic support funds are the most flexible of AID's funds, with the fewest restrictions on their use. Therefore, *Congress could direct the General Accounting Office to examine such funding mechanisms and assess their feasibility as funding sources for maintenance of biological diversity.*