chapter 13

Forestry Technologies for U.S. Tropical Territories

Contents

Figure

Chapter 13

Forestry Technologies for U.S. Tropical Territories

HIGHLIGHTS

- The potential of forestry to contribute to economic development has been underestimated in the U.S. tropical territories.
- Although large-scale industrial forestry is not practical in the island territories, many other technologies exist that can help satisfy the needs of growing populations and sustain the forest resources.
- Implementation of suitable technologies will rely on developing skilled personnel within these regions and on raising decisionmaker and general public awareness of forest resource potentials.
- until local natural resource agencies have adequate staff and funding, Federal assistance will be required. Without this, needed resource productivity and development opportunities will be lost.

FORESTRY IN THE U.S. TROPICS

Until recently the forests in the U.S. tropical territories have not been managed actively. In fact, while overexploitation is not now a problem in most areas, poor land uses in the past have left the islands with significant amounts of abandoned agricultural land and relatively unproductive secondary forests.

The U.S. tropical territories also are characterized by growing populations, rising imports of food, fuel, and wood, dependence on Federal income supports, and generally high unemployment. Unemployment in Puerto Rico, for example, exceeds 20 percent in general and approaches 35 percent in rural areas (19). Development of appropriate forestry and agroforestry technologies could help alleviate some of these problems. Such technologies could provide local substitutes for imported products, providing employment and income opportunities, and protecting against erosion, floods, and similar environmental damage.

The following discussion of technologies that offer opportunities for sustainable development of forest resources in the U.S. tropical territories is organized in parallel with chapters 7 through 10. It deals with conservation of undisturbed forests, reducing overcutting, managing disturbed forests, and forest technologies to support agriculture. Two other sections, corresponding to chapters 11 and 12, discuss technologies for resource development planning, professional and technical training, environmental education, research, and technology transfer.

TECHNOLOGIES

Technologies for Undisturbed Forests

Few truly undisturbed forests exist in the U.S. Caribbean and western Pacific territories. Those remaining after the past century's history of deforestation for agriculture are mostly in inaccessible regions. There are, however, considerable acreages of secondary forest, some old enough to fit this report's definition of undisturbed forest. * Two methods are available to sustain these forest resources: 1) preserve samples of forest ecosystems in parks and protected areas, and 2) make undisturbed forests more valuable by increasing sustainable production of marketable nonwood products (ch. 7).

Sample Ecosystems

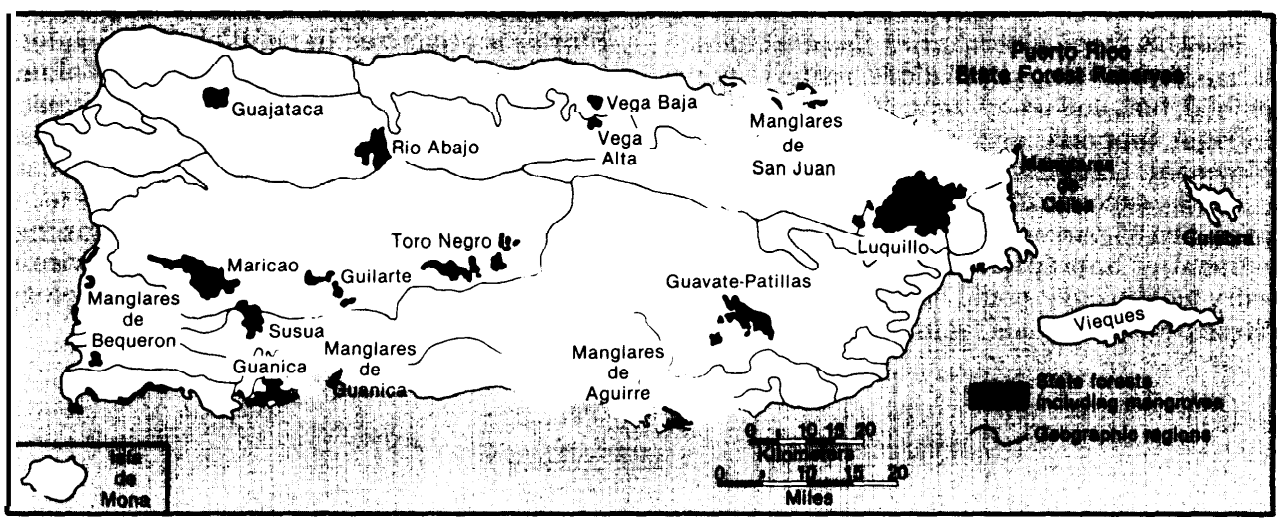
Protected forest areas are well-established in Puerto Rico and the U.S. Virgin Islands, but few have been created in the western Pacific. The most valuable areas of primary forest and the remaining rare and endemic tree species are protected in Puerto Rico in the National and Commonwealth Forest reserves and in the U.S. Virgin Islands National Park. That park covers nearly three-quarters of St. John Island. The Caribbean National Forest in Puerto Rico was established in 1903 and now encompasses 28,000 acres of rain forest. The first Commonwealth forest reserves were formed in 1918. Now 13 of these cover 59,000 acres and they include moist and dry forests and mangroves (fig. 32). Protection policies for these areas have been fairly effective and remain strongly supported.

In 1976, the Caribbean National Forest** was designated a biosphere reserve under the UNESCO Man and the Biosphere (MAB) program. This program is designed to protect representative samples of major ecosystems and to promote ecologically sound land-use practices in adjacent areas. The forest was subsequently divided into a central zone where no recreation or management activities are allowed, surrounded by a recreation zone that attracts hundreds of thousands of visitors each

*Undisturbed tropical forests are areas where trees are the dominant woody vegetation covering at least 10 percent of the ground and where trees have not been cut during the past 60 years.

**The Caribbean National Forest also is known as the Luquillo Experimental Forest and the Luquillo Biosphere Reserve.

Figure 32.—Puerto Rico Commonwealth Forests



SOURCE: The *Geography of Puerto Rico* (Chicago: Aldine Publishing Co., 1974).

year, and an outer zone where the U.S. Forest Service Institute of Tropical Forestry conducts forest management research. Part of the Virgin Islands National Park (11,000 acres) and Puerto Rico's Guanica State Forest (10,000 acres) also have been designated MAB biosphere reserves (10).

Creation of a protected area system has been considered in the Pacific Islands for some time, but little has been done. In 1956, the High Commissioner of the Trust Territory of the Pacific Islands established the Ngerukewid Islands Wildlife Preserve (the Seventy Islands Preserve) in the Limestone Islands of Palau (11). This includes war sites and sites where the Yapese people carved wheel-shaped stone money that reaches up to 8 feet in diameter. This preserve also protects the endangered Micronesia megapode, the dugong, and other threatened plant and animal species.

The U.S. National Park Service administers the War in the Pacific National Historical Park on Guam, which is forest-covered. The U.S. Forest Service helped the Guam Department of Agriculture establish the Patti Point Natural Area on Andersen Air Force Base. In 1973, the U.S. Fish and Wildlife Service created the Rose Atoll National Wildlife Refuge at the request of the government of American Samoa. Since then, little activity has been undertaken to establish protected areas.

Opportunity: Characteristics of the western Pacific Islands such as high endemism, fragile ecosystems, and dependence on surface water make protection of some forest areas on these islands appropriate. National conservation plans are needed to identify sites that should be protected as permanent preserves and sites to be protected until management's plan can be instituted.

A team effort by appropriate island agencies, U.S. Federal agencies, and local colleges could be used to inventory resources and to design parks and reserves. This would build local managerial capacity and ensure that protected areas fit local needs and conditions.

Current resource inventories conducted cooperatively by local and Federal agencies provide a base of information for protected area establishment. These efforts could be expanded to produce comprehensive natural resource surveys on all the major islands.

Making Undisturbed Forests More Valuable

One method to sustain forest resources is to promote the profitable and sustainable use of animals and plant products other than wood. This could increase the perceived value of the forest without increasing the motivation to overcut its trees. The potential to develop such products is not large in Puerto Rico and the U.S. Virgin Islands, but some opportunities exist, such as small-scale production of honey, bamboo products, eucalyptus leaves and oil, molluscicidal ***Phytolacca,*** and sphagnum moss for nursery planting (12). The U.S. Forest Service has no permanently assigned economic botanist and local governments have no plans to assess or develop such resources.

The potential for this sort of development 'seems greater in the western Pacific islands because they have more subsistence-oriented economies. Gathering activities are a normal part of subsistence life on the largely communally owned western Pacific islands. However, this has endangered the Micronesia megapode, a ground-nesting bird whose eggs are considered a delicacy; the dugong, whose vertebrae have been used as wrist and ankle ornaments; and the fruit bat, among others,

Efforts to manage the fruit baton a sustained basis, including maintenance of its forest habitat, are under way. The Yapese fruit bat is endemic and is Yap's only indigenous mammal. These bats are a traditional food in Yap and are highly sought after by inhabitants of the Marianas as well. The fruit bats also are believed important for fruit tree pollination and seed distribution, especially for mango trees (6). Recently the Government of Yap State banned hunting of the bat. The U.S. Forest Service is

red

E m g g
g m
w US w

n e ga ng e o ogy and managemen of he f u ba o ha hun ng an e ume w hou ndange ng he ba popu a on o o ng h e they p o de o he o e

Oppo un ty A e men of oppo un e o de e op fo e p odu ndu e e pe a y mpo an n he we e n Pa fi Ca efu p an n ng equ ed o a e he h ea po ed by ga he ng a e o nd genou an ma and p an fe The po a a e and b o og a ud e unde way o manage fru ba popu a on nd a e an n e e n de e op ng m no o e p odu Fu he oppo un e a e n d a ed by e pe en e n o he op a eg on

Examples include harvest of nonwood forest products such as essential oils and mangrove aquatic organisms, and innovative forest resource management programs that have the potential to reverse a trend of overharvest.

Technologies to Reduce Overcutting

Methods to reduce the rate of forest degradation from wood harvest and use include: 1) improved harvesting and transport technologies to reduce the extent of forest harvested and to reduce the adverse impacts of harvesting and transport; and 2) reduced demand for wood products through more efficient use of available products (ch. 8).

Industrial Wood

Relatively little potential for full-scale industrial forestry exists in the U.S. territories due to limited forest acreages, topographical factors, competing land uses, small landholdings, high land prices, and uncertain land tenure. However, potential does exist for small-scale industries that can serve domestic markets and contribute to rising living standards (24).

For example, portable sawmills were introduced in Puerto Rico in 1982, Teak, mahogany, and Caribbean pine have been successfully and economically thinned, milled, and marketed by the Puerto Rico Forest Service. There are plans to expand this program. Portable sawmills, combined with regulation of exploitation, are probably the best-suited harvesting systems for the western Pacific as well.

Portable sawmills are especially appropriate for cooperative use because they can be used as needed and temporarily retired without significant economic disadvantages. They require little operator training (24). Because they can be pulled to the harvest site behind small vehicles, they cause less harm to thin soils than larger systems. They do not require an extensive road system and they leave bark and branches on the site, thus reducing nutrient loss.

Small-scale sawmills in rural areas can stimulate development of local workshops with corresponding effects on rural employment. These

Photo credit: Williarn Balrner

This plant in Cambalache State Forest, Puerto Rico, is treating posts from both private and Commonwealth lands and is helping demonstrate the opportunities for growing and using local wood.

effects could be expanded by introducing facilities such as simple and inexpensive solar kilns or wood preservation equipment. This type of forest industry development can be upgraded as workers improve their skills, local management masters the task, and local markets grow to absorb increased production (24).

Opportunity: Small-scale forest industries that supply local markets could serve as a starting place for a more comprehensive local forestry industry. Rural centers could process wood products from portable mills. This would encourage the creation of a forest constituency to encourage local private organizations and governments to take action to sustain the forest resources. Governments in both the Caribbean and Pacific territories are promoting the creation of private cooperatives in agriculture, although none have yet been organized in forestry.

Wood Fuels

Little need exists to reduce demand for most local wood products in the U.S. territories. Imports have substituted for products previously derived from local forests. However, wood fuels are in short supply in some areas, and wood fuel technologies can be used to increase the efficiency of forest product use.

25-287 0 - 84 - 19

Firewood is not in high demand in Puerto Rico and the U.S. Virgin Islands, except for some recreational uses. There is significant demand for charcoal for roadside food stands and home uses; charcoal is imported from the United States, Germany, and the Dominican Republic (12). Locally produced charcoal is made by traditional labor-intensive methods using earth kilns. As costs of importing fossil fuels increase, the demand for biomass fuels should increase.

The U.S. Forest Service uses a more efficient, portable kiln on St. Croix, to produce charcoal with wood from thinning and other timber stand improvement work in the Estate Thomas Experimental Forest (23). The Puerto Rico Forest Service operates one demonstration kiln but more activity in this area maybe necessary to encourage timber stand improvement (22). In addition, because the demand for fuelwood is relatively low in U.S. tropical forests, they offer an opportunity to study charcoal production and conversion technologies in a stable environment.

The demand for fuelwood in the U.S. western Pacific is rising because of increasing populations and high fossil fuel costs. Perhaps one-third of the Micronesia people have left their rural lands and are concentrated in urban areas (38). They need inexpensive energy for cooking. The availability, transport, and price of fuelwood can vary greatly on an island and from one island to another. Some towns no longer have readily available sources of fuelwood, although accessibility to distant supplies is increasing as roads are improved.

Improved small-scale charcoal production technologies could make wood a more important energy source. Markets for charcoal may exist in Japan and other Asiatic nations. However, this type of commercial involvement should not be promoted until it has been determined that the islands could meet their own needs on a sustained basis. It is likely that man-made plantations and woodlots would be required, although this could also provide a use for scrub and for senescent coconut trees.

Opportunity: Senescent coconut plantations, a major vegetative cover in the U.S. Pacific Islands, could be used to produce charcoal until conventional firewood plantations are established. Old coconut stems cannot be left to rot because of the risk of infestation by the Rhinoceros Beetle, which breeds in the old stems and attacks the newly planted nuts. Unmanaged coconut plantations also provide larval mosquito habitats in water-filled old nuts. The mosquitos have been known to carry elephantiasis, encephalitis, and dengue* (13).

Coconut stems are unsuitable as firewood due to a high moisture content and low density, but they have high thermal efficiency as charcoal. The technologies for producing coconut stem charcoal are simple and well-known. For example, after air-drying, short billets can be burned in simple kilns or 40-gallon drums.

Development of a coconut stem charcoal industry also could provide some spinoff benefits. Coconut shells produce a high grade pharmaceutical charcoal suitable for activation that is used as a filter in many industrial and pharmaceutical uses. High-value, low-volume commodities such as this are potential export products (18).

Technologies for Disturbed Forests

Most of the island territories were cleared in the late 19th and early 20th centuries for export agriculture—primarily sugarcane, tobacco, and coffee. When production declined, rural populations reverted to subsistence and local cash crop production, allowing forests to return on some areas. More recently, as populations migrate to urban areas and as income support programs replace subsistence agriculture, the area of abandoned agricultural lands is again expanding and much of this is reverting to secondary forest.

Data on the extent of secondary forest are not yet available for most of the western Pacific territories, but Guam is estimated to have about

*OTA is conducting an assessment of biomedical research and related technologies for dealing with tropical diseases.

70,000 unmanaged acres covered with brush or trees and 50,000 acres of open or grass-covered land (38). Secondary forest covers 800,000 acres of Puerto Rico. Forest and brush cover 30,000 acres of the U.S. Virgin Islands.

Much of this land could be used to produce timber and other forest goods, as could some lands that are not naturally regenerating, particularly the savanna lands of the western Pacific. Significant potential for commercial forest plantations exists only for the larger islands of Puerto Rico, American Samoa, Guam, Ponape, and Palau. But small-scale timber stand improvement and village woodlots could supply some needs on smaller islands.

Management of Socondary Forests

Brush and secondary forest in the U.S. Virgin Islands generally is scrubby and of little interest for wood production. A small area on St. Croix might be suitable for this use, but high land prices and land speculation probably prevent secondary forest management from being perceived as a profitable investment.

Puerto Rico has large areas of secondary forest and its management is a primary focus of the U.S. Forest Service Institute of Tropical Forestry (ITF). ITF is conducting an inventory of secondary forest in Puerto Rico. Although most of the trees have little commercial value, the inventory reveals that some valuable timber species are regenerating on abandoned lands. Standard timber stand improvement techniques could result in valuable future timber stands (22).

Some of these techniques such as enrichment line plantings of mahogany are being used in the National and Commonwealth forests. Subsequent harvest provides income for the Puerto Rico Division of Forestry and supports further management of the National Forest. Even though improved timber stands probably will not become a major land use they do have potential to increase the value of private forest landholdings held for other purposes, such as recreation, second homes, or inheritance.

Wood harvest in the western Pacific is limited to fuelwood, some home construction materials, individual tree use by the crafts industry, and some commercial harvest of mangroves (32). Little of the forest has significant potential for commercial timber exploitation because of low volume and poor-quality trees (38). Secondary forest management, however, has considerable potential to provide locally used products—crafts, poles, construction materials, firewood, and charcoal. Cottage-based industries could be developed around local forest products.

Opportunity: Even though managed secondary forest is not likely to become a major land use in the U.S. territories, it merits consideration as an improvement over unmanaged, low-quality brush or forest land unsuitable for agriculture. In Puerto Rico, managed secondary forests can provide a first harvest before conversion to plantation forestry or increase the value of land deliberately held out of intensive production [e.g., recreation sites).

Additionally, secondary forest management will provide a means for the National and Commonwealth forests to gain income for further forestry and preservation efforts. In the western Pacific, managed secondary forests can sustain the supply of raw materials for locally used products. Both efforts require further information on the extent, composition, and quality of secondary forests, and on the current and potential uses of both native and introduced species.

Reforestation

Plantations require more intensive management and a greater initial capital outlay per acre than secondary forests, but usually produce greater wood yields because stocking rates and species composition are controlled. Plantation forestry has greater potential in Puerto Rico than in the other territories because of higher average per capita income and greater land tenure security. An estimated 200,000 acres are suitable for plantation for-

estry (35,36). No plantation inventory has been conducted in Puerto Rico, but between 35,000 and 95,000 acres of plantations, primarily Caribbean pine, are estimated to exist. Many of these plantings were established in public forests during the 1930's (19).

The yield of a pine plantation in Puerto Rico's moist and wet forests is about 25 cubic meters per hectare per year (2,000 board feet/acre/year) if production is averaged across the rotation (40). Intensive thinning could increase this yield and produce 1,000 or more posts per acre across a 20-year rotation. Thus, establishment of 100,000 acres of softwood plantation could produce 2000 million board feet of lumber per year once sustained yields were achieved.

In 1981, 83 million board feet of softwood lumber, 58 million square feet of softwood panels and veneers, and 195,000 poles were imported to Puerto Rico. The land potentially available for plantations could satisfy that level of demand. However, demand is growing at about 5 percent annually. The planting of 5,000 acres per year for the next 20 years would result in 100,000 acres of plantation, but major harvests would not begin until the 21st year.

g g R g

Similarly, if 100,000 acres of high-value hardwood plantations were established, the average annual production would be about 70 million board feet. In 1981, 11 million board feet of hardwood lumber and 97 million square feet of hardwood panel and veneer were imported. Here again, the current demand could support a planting program of this scale. Puerto Rico, however, would still import other products such as paper, furniture, veneers, and composites.

Plantation forestry has not attracted much private investment on Puerto Rico for several reasons:

- Private landholdings tend to be small, reducing cost effectiveness of intensive forestry activities and increasing the competition between forestry and other land uses (e.g., agriculture or recreation).
- Shortages of capital and credit for small-plot landholders may not permit investment by rural people in plantation forestry,
- Many private landholders in Puerto Rico hold land for its recreational or future development values and may not be interested in its productive value.
- High land prices and a law limiting private or corporate landholdings to 500 acres may be disincentives to investment in plantation forestry.

Two Federal programs administered by the USDA Agricultural Stabilization and Conservation Service (ASCS) are designed to aid private landowners in forestry activities: the Agricultural Conservation Program (ACP) and the Forestry Incentive Program (FIP). Both provide cost-sharing to small-plot landowners.

FIP and ACP were used only in Puerto Rico. Between 1975 and 1980, there had been only 23 participants in the FIP program in Puerto Rico, reforesting only 213 acres (27). ACP allows greater eligibility and is an older program. From 1936 to 1980, Federal ACP incentives helped to plant over 30,000 acres in Puerto Rico for soil erosion control and commercial purposes. There have been no participants in FIP or ACP in the U.S. Virgin Islands or the U.S. western Pacific territories.

ACP is designed to take land out of annual crop production that would presumably be worth more to society for its environmental services when fallow than for its products when cropped. FIP is oriented toward the greatest return on invested money rather than to widest spread reforestation and, thus, landowners with greater earning capacity have preference over those with greater need for assistance. Neither program assures income during the years before harvest (7).

In recent years, Federal policy has changed emphasis from cost-sharing to income tax incentives to effect forestry practices on private lands. So the budget has been reduced for the ACP and FIP programs. Forestry incentives in Puerto Rico are lost with this change, as citizens there are exempt from paying U.S. Federal income taxes.

Successful programs to stimulate private investment in forestry require the simultaneous development of extension and education programs, nursery production and delivery systems, and trained foresters and forest technicians. Loggers, sawmill operators, and lumber treating and drying experts must be trained, and marketing systems must be developed (19). Since it takes years to develop some of these systems, their simultaneous development must be part of a long-term continuing effort. This requires a stable political commitment.

Until recently, slow progress in forestry has been due to a lack of Federal and local funding and political support. The Commonwealth government for at least 15 years had not put a high priority on forestry. But Puerto Rico now has the legal (Forest Law No. 133 of 1975) and administrative structure (through the Department of Natural Resources) to develop a strong and effective Forest Service.

The Puerto Rico Department of Natural Resources (DNR) has recently embarked on an ambitious program to bring private landowners into commercial forestry. This program relies heavily on U.S. Federal cost-sharing programs for private landholders and on funding from U.S. Forest Service State and Private Forestry grants. Unfortunately, these Federal funds are

declining. The program is organized into three phases, as follows: a media program, harvest technology demonstration, and organization of forestry cooperatives.

The U.S. Virgin Islands also has a reforestation program for private landowners, funded by the U.S. Forest Service State and Private Forestry program and by the local government. This program, in operation since 1967, operates a nursery, runs an urban forestry program on public lands, and runs a rural reforestation program, An average of 25 to 30 acres are reforested each year (3).

The goal of the reforestation program is to provide a local supply of high-value hardwoods, especially mahogany. As incentives, the Virgin Islands Forestry Program offers low-cost rental of land-clearing equipment as well as free seedlings and technical advice. In addition, the U.S. Virgin Islands Government offers a 95 percent property tax rebate for lands retained in agriculture or forestry, Most reforested lands are those too steep for cultivation or grazing and, thus, the program indirectly reduces runoff and erosion.

The urban forestry program sponsors planting of mahogany and other species on public lands. Since the potential volume of wood is small in the U.S. Virgin Islands, local production of high-value products seems appropriate. Small and low-value trees removed during thinning could be used for fence posts and charcoal. Even street and yard trees can be valuable: an estimated 500,000 board feet of merchantable mahogany exists in the islands (23).

A small wood crafts and specialty furniture industry exists on St. Croix. Urban and roadside trees that must be removed for other reasons supply much of the raw material. Branches and crotches in the trunk provide figured wood and can be the most valuable part of the tree. This use of available wood could be a model for economic use of wood where large-scale commercial forestry is not feasible.

Transportation costs and insecure land tenure hinder timber production for other than local uses on most western Pacific islands. Some commercial exploitation of lumber for local use could be allowed on larger islands, but in general the forests of the western Pacific islands are too meager to sustain commercial development of forest products such as sawlogs, lumber, wood chips, or paper pulp (15). Local markets for firewood, charcoal, local construction materials, crafts, and fruit crops provide opportunities for investment in tree plantations. Research and demonstration plots of native and introduced species and methods of transferring technologies to villages and private landholders need to be established, especially for intensive firewood plantations.

Opportunity: The U.S. Congress and the U.S. Forest Service could jointly provide political and financial support for DNR and Virgin Islands Department of Agriculture programs to encourage plantation forestry to increase self-sufficiency and build local forest industries. Congress could communicate to the heads of U.S. Caribbean governments the importance Congress places on sustainable development of local forest resources. The Forest Service could provide support for local programs through State and Private Forestry grants. Such actions are needed to ensure continuity of programs despite political changes.

The Forest Service could provide increased technical assistance to U.S. tropical territories in the Pacific to identify areas suitable for investment in plantation forestry and to develop technologies appropriate for forest management under the tropical island conditions. The Forest Service, in cooperation with the Federated States of Micronesia, is using soil and vegetation maps to perform the first forest resource assessment of those islands. Similar assessments could be done to develop plans for other areas.

Forestry Technologies to Support Agriculture

Agroforestry and watershed technologies are designed to use trees to support agricultural and other resources. Coastal resources, in particular, are affected by island forest manage-

Photo credit: William Balmer

Urban forestry in the U.S. Virgin Islands. These trees (hybrid mahogany) will be harvested for lumber

ment. Elevated tropical islands ("high islands") have steep slopes and, where cleared, tend to have high erosion rates. The estimated erosion rates in the U.S. Caribbean compared with the continental U.S. average are 15 times higher for ungrazed forest land, nearly 10 times higher for cleared cropland, and 18 times higher for rangeland.

Agroforestry

Agroforestry is a traditional practice in Puerto Rico (coffee/shade tree, fruit tree/plaintain) and on many Pacific islands (tree/yam, coconut/breadfruit). Teak/forage agroforestry has been practiced in the U.S. Virgin Islands, although this has little potential for expansion (23).

Traditional agroforestry systems are becoming obsolete because of Federal food assistance programs and other alternatives to subsistence food production. The necessary skills and knowledge gradually are being lost on many islands or may reside only in the oldest generation (38). The U.S. Forest Service is beginning a small project to evaluate traditional agroforestry in Micronesia. Through its vegetation mapping project of the Federated States of Mi-

Photo *credit: C. Whitesell*

Breadfruit—used here to make a canoe—is often used in traditional agroforestry practice in the western Pacific. Although agroforestry has declined in these islands, it retains considerable potential as a productive and sustainable land use

cronesia and Palau, the Forest Service has located considerable acreage that is still used for traditional agroforestry. It can be a sustainable and productive land use, especially on slopes where open-land, bare-soil types of agriculture result in erosion and subsequent siltation.

The U.S. Forest Service Institute of Pacific Islands Forestry is pursuing some research in agroforestry. It includes species trials and nursery development in the Marshall Islands and Yap, studies of the effects of fertilizer on growth and yield of certain agroforestry crops, and growth studies of some tree species. The Institute of Tropical Forestry in Puerto Rico has performed a survey of agroforestry techniques in Latin America (37) but is not conducting further research on this topic.

Opportunity: Improved agroforestry systems alined with traditional techniques should be acceptable to people already using agroforestry and transferable to new practitioners. Agroforestry in place of cleared-land agriculture, especially in mountainous areas, could reduce erosion and siltation and provide a sustainable use for some degraded and marginal lands.

In Puerto Rico, which has better road systems and markets than the other islands, agroforestry producing a cash crop would probably be best accepted. The USDA Mayaguez Institute of Tropical Agriculture in Puerto Rico could perform trials on its experimental lands in cooperation with the U.S. Forest Service.

In the western Pacific, subsistence agroforestry could be appropriate in the short term,

combined with research on species suitable for cash-crop agroforestry that could be implemented as markets develop. Western Pacific trials could be performed jointly by the U.S. Forest Service, the University of Guam, the Nekken Forestry Experiment Station on Palau, the Metalinim Forestry Station on Ponape, and with other island organizations and agencies.

Watersheds

The most pronounced impacts of forest loss in the U.S. tropical territories are on island streams and coastal resources. Deforestation has caused permanent streams on some islands to disappear and it contributes to increased runoff, flooding, water shortages, and erosion. Siltation has harmful effects on lagoons and reefs, affecting fish and other marine resources important to island people,

Most upper watersheds in Puerto Rico have steep slopes and many should remain forest-covered. In general, these lands are also too steep for significant wood harvest. With appropriate regulation, however, some gathering, recreation activities, and residential development might be allowed.

The U.S. Virgin Islands have major water problems. There are no permanent streams on the islands. Island aquifer water levels are declining as growing populations pump out more water than is recharged. Water supplies are derived primarily from costly desalinization of sea water and water barged in from Puerto Rico. Watersheds in the U.S. Virgin Islands are privately owned and mostly brush covered. Some livestock is run on these lands, but there is little agriculture, except on St. Croix. Nothing is done collectively to manage these lands for water retention and erosion prevention.

Natural siltation in the western Pacific region is greatest around high islands. Elevated watersheds collect and accelerate runoff. Around these islands, however, mangrove forests and stands of seagrass act as filters to remove sediments before the runoff water reaches lagoons or reefs. In many areas, erosion and marine siltation have been accelerated by deforestation, so that plumes of eroded soils often are seen near the mouths of streams in Micronesia. The silt represents a lost resource and pollutes the marine environment. Activities that aggravate soil erosion include cultivation practices, construction, roadbuilding, and burning, which removes vegetative cover from hills, Due to repeated burnings on Northern Babeldaob (Palau), formerly permanent streams now run only when rain falls, and then they are often fast and muddy (5),

Photo credit: William Balmer

This plantation of blue mahoe *(Hibiscus elatus),* a valuable hardwood that gorws well on many moist sites in Puerto Rico like others planted on private lands, was established for watershed protection

Opportunity: Resource managers disagree on the relative advantages of reforesting watersheds or leaving them in grass and brush cover. Reforestation reduces runoff and erosion rates and so increases catchment lifetimes and protects coastal resources. Some experts believe it might increase aquifer recharge. On the other hand, trees use more water than grass and brush, so tree planting reduces the amount of water immediately available to catchments. Degraded pasture and brush are more susceptible to frequent burning and conversion to unsustainable land uses than are managed forests (22). A careful assessment is required to determine the optimal vegetation cover for each watershed area. There seems little doubt that steep coastal slopes should be forested to reduce erosion and, thus, reduce siltation of lagoons, reefs, and mangroves.

Resource Development Planning

Most conversion of tropical forest land to other uses is done without adequate consideration of whether the natural and human resources available at the site can sustain the new land uses. Resource development planning is a systematic attempt to match land development activities to the capabilities of the specific sites (ch. 11).

Puerto Rico and the U.S. Virgin Islands have been extensively studied and are classified under the Beard system, based on floristics and species composition (1,2); the Holdridge Land Classification System, based on precipitation, biotemperature, and potential evapotranspiration (8,9); and the USDA Soil Conservation Land Capability System (28). Because land uses and vegetation are continuously changing, detailed land classification data require continued updating and revision.

In the U.S. tropical territories, little use has been made of economic and social assessments for forestry development. The Puerto Rico Department of Natural Resources has conducted a benefit-cost analysis of an expanded forest tree planting and wood-use program based on small-scale harvesting (19). DNR has also prepared a financial analysis of small-scale private forestry (20).

Knowledge of the remaining tropical forests in the western Pacific, the local uses of tropical forest products (e.g., medicines), and local customs involving forests is insufficient for planning. Information on the nature and magnitude of the forest resources, including vegetation, land use, watershed, wildlife, commercial timber, and ecosystems is either lacking or too scattered to assist forest management planning and protection programs.

The U.S. Trust Territory of the Pacific Islands (TTPI) Government contracted with the U.S. Soil Conservation Service and the U.S. Forest Service to map the soils and vegetation cover types of the Republic of Palau and the four states of the Federated States of Micronesia. These soil and vegetation maps are used in land-use planning and are being used to conduct the first forest resource assessment of the Federated States of Micronesia. Preparation of State/Territorial Forest Resource Program Plans is expected to be completed in 1983.

Similar assessments could be conducted elsewhere in the western Pacific (38). Current guidelines and funding permit the U.S. Forest Service to conduct resource inventories and forest management research only when cooperating island governments provide funding and field assistance (4). The U.S. Forest Service has memoranda of understanding with each of the island governments regarding resource assessments, but inadequate funding has hindered completion of these efforts.

A complementary series of assessments by the U.S. Fish and Wildlife Service could determine damage by and control measures needed for introduced animal species, effects of land uses on coastal organisms, conservation measures for endemic species, and other topics. The U.S. Fish and Wildlife Service has recently completed an ornithological and botanical survey on Guam. Additional "terrestrial surveys" in the northern Mariana Islands are under way. Similar surveys are expected to be undertaken on Ponape, Truk, Yap, and Kosrae (17), but

budget reductions have postponed these efforts (39).

Opportunity: Resource development planning could help identify where agricultural activities should be limited and where they might require special designs. Similarly, such planning could help determine optimal sites for roads from both ecological and social points of view. To supplement this, island government agencies could prepare environmental impact statements, hold public hearings, and seek approval from the appropriate local resource agency to control and monitor logging, land clearing, road construction, coral mining, etc. (38). The U.S. Forest Service and Army Corps of Engineers could provide assistance when road-building activities are being planned.

Education, Research, and Technology Transfer

Lack of awareness of forest resource values, shortages of forest resource professionals, and insufficient technology transfer are institutional constraints that inhibit development of sustainable forest systems in the U.S. Caribbean and western Pacific territories (ch. 12).

Environmental Education

Government decisionmakers in the U.S. territories have expressed growing interest in sustaining and developing their forest resources. However, this interest may be temporary unless people at all levels of society seek alternatives to resource-degrading activities and invest in resource-sustaining technologies. Motivating such action is the goal of environmental education.

Like other New World colonies, many Caribbean islands were almost completely cut over to produce agricultural export crops between 1800 and 1898, producing a "burn the forests" attitude toward development (14). As yet, rising incomes and education have not brought about a widespread environmental awareness movement such as that in the continental United States. The result has been a continuing view that the forest is useful for recreation and tourism but must be removed to make way for more productive investments (7). This has begun to change only recently.

A primary forestry objective of the Puerto Rico DNR is to change public attitudes through education and incentives to involve people in forestry policy and activities. DNR has one or two field agents in each of the five regions of Puerto Rico who receive 2 weeks of forestry training. This training is to be updated regularly. In addition, pamphlets on forest planting may now be found in all Agricultural Extension Offices and a new pamphlet on the financial opportunities of timber production on private lands will soon be disseminated (21).

Education also has been a major focus of U.S. assistance to the western Pacific territories. Primary and secondary education are compulsory in Micronesia, and the Federal Government has helped create several community colleges and the University of Guam. Each of these has been designated a land-grant college, giving them access to Federal support for agriculture and forestry.

Many of the inhabitants of the island territories can be reached through education because of the young age structure. For example, 44 percent of Micronesia's population in 1980 was under the age of 15. Under the Compact of Free Association agreement, the U.S. Government will continue to fund public education, including a $3 million grant for a higher education scholarship fund. But many of these scholarships are based on financial need and not on the field of study needed for economic growth (33). Increased exposure to environmental education in primary and secondary schools, together with awarding scholarships to students interested in resource development, may be the first steps toward creating environmental awareness.

Opportunity: The Puerto Rican Government could begin to encourage resource-conserving attitudes by increasing environmental education at all levels. Three interacting activities that could have significant effects are:

1. Create training courses for primary and secondary level teachers using protected forests as demonstration areas.

Photo credit: USFS-ITF

Youth conservation worker programs can introduce local people to basic principles of ecology and forest management. Here, Young American Conservation Corps enrollees plant mahogany" in a Puerto Rican public fores{

2. Increase use of local youth conservation workers in National and Commonwealth forests and other natural resource areas. *
3. Make forest resource management an area of study at the University of Puerto Rico either by developing a resource management curriculum or by creating a "center of excellence" to provide a focus of interest and efforts on tropical forest resources (ch. 12).

Environmental education in the U.S. western Pacific seems to have had little effect (15). The U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, National Marine Fisheries Service, Peace Corps, and local colleges could collaborate to produce course materials that stress resource awareness and encourage the territorial governments to include resource and conservation programs in school curricula. They could also translate technical environmental information for general public use (29).

*Currently, Young American Conservation Corps (YACC) workers in Puerto Rico are trained by ITF personnel and assigned to Commonwealth and National Forests (30).

Professional Education and Technical Training

The U.S. tropical territories do not have a strong constituency concerned with forest conservation. Developing such a constituency and integrating natural resource considerations into economic development both will require personnel with substantial knowledge and expertise in natural resource management in general and tropical forestry in particular. In the short

term, a limited number of resource professionals with expertise in tropical forestry can be attracted to the islands from the mainland. But the Forest Service reward structure inhibits this, and lack of scientific facilities and funding hinder university personnel. In the long run, an effective method to educate and train local people is needed.

The University of Puerto Rico lacks a forestry curriculum. Puerto Rico and the U.S. Virgin Islands support only two students per year in forestry and forest ecology training. A similar dearth of forestry specialists exists in the U.S. western Pacific. No forestry curriculum exists at the University of Guam, although officials have expressed a strong interest in developing one (4). The closest forestry school is at the forest ranger school at the University of Bulolo in Papua New Guinea. The need for trained foresters and forest technicians is particularly acute as the island governments expand their government forestry agencies and forestry plans.

Opportunity: Fostering natural resource management training and education in the U.S. territories could be achieved in four ways:

1. Students interested in natural resource management could be encouraged to apply for scholarships at U.S. schools and internships with private organizations. The best sponsors for such scholarships might be private firms with production facilities or markets in the territories.
2. Scholarships also could be provided for forest technician students to attend natural resource management programs in tropical country schools (e. g., Costa Rica, Venezuela, Papua New Guinea), where technical training may be more relevant.
3. Forestry/forest ecology/conservation curricula could be developed at the University of Puerto Rico and the University of Guam, possibly using McIntyre-Stennis funds. *
4. Forestry institutions in each region could be designated "centers of excellence" in education and research related to tropical forestry resources and as such could provide graduate study and research facilities for students from U.S. and tropical universities (ch, 12).

*The McIntyre-Stennis Act of 1962 authorizes cooperative forestry research between the U.S. Department of Agriculture and state and land-grant universities.

Research

The U.S. Forest Service Institute of Tropical Forestry (ITF) was established in 1939 as a result of congressional recognition that lack of technical knowledge hindered successful reforestation and forestry efforts in Puerto Rico. ITF uses the National Forest, some Commonwealth forests, and the 124-acre Estate Thomas Experimental Forest in the U.S. Virgin Islands for research. ITF conducts cooperative research with agencies such as AID, the Peace Corps, U.S. Fish and Wildlife Service, and several universities and Caribbean nation governments. Recent ITF research is intended to:

- develop guidelines to establish and manage timber plantations (primarily pines and exotic hardwoods) without adversely affecting site productivity;
- develop knowledge about biological potential of timber production from secondary forests, with due regard for other environmental concerns; and
- develop knowledge about forest wildlife habitat requirements and techniques to manage these habitats (focusing on the endangered Puerto Rican parrot and associated species).

ITF research activities have traditionally focused on basic ecology and industrial forestry. The latter is not widely applicable to the U.S. Caribbean. Only about 6 percent of landholdings are 100 acres or greater, but these cover 65 percent of farmland. Most of these larger holdings are commercial farms on the coastal plains or coffee plantations on hilly regions. Many of the large-plot landowners in forested regions may be real estate investors waiting for land prices in the U.S. Caribbean to increase, and as such may be uninterested in productive uses of their land. Environmental education and extension efforts could be made to change

this attitude and some commercial forestry research should be conducted for these landowners.

However, research directions have begun to change in recent years. Since the Forest and Rangeland Renewable Resources Research Act of 1978 (Public Law 95-307) and the concurrent growth in interest in international forestry, ITF has conducted a survey of agroforestry in Latin America (37) and studies of fuelwood production (30). Yet, ITF budgets have been cut back continuously for the past few years and the primary focus is still on industrial production.

Industrial forestry research at the ITF could be complemented by research aimed at the needs of Caribbean society in general (e.g., environmental services, esthetics) and of the small-plot landholder. Nearly 90 percent of the farmland ownerships (covering 270,000 acres), are less than 48 acres (26). Most of these landowners have low incomes. Rural unemployment is high, implying a need for labor-intensive technologies. Profitable agroforestry systems to produce both subsistence and commercial products need to be developed and disseminated. Industrial forestry research could be appropriate for this group if forestry cooperatives were organized. Research areas such as watershed and wildlife management, which provide benefits to society in general, deserve more attention, particularly given the water problems in the U.S. Virgin Islands.

Although the U.S. Virgin Islands have little agriculture and little potential for commercial forestry, protective forestry activities are necessary to preserve resources for the inhabitants and for tourism. ITF research in the Estate Thomas Experimental Forest could be expanded to include experimental urban forestry, watershed analyses, and other appropriate topics. More research personnel and funding and selection of research topics more relevant to local research needs are necessary.

The American Pacific Islands Forestry Research Work Unit, at the Institute of Pacific Islands Forestry, is part of the U.S. Forest Service Pacific Southwest Forest and Range Experiment Station. The Research Work Unit has only three professional staff comprising 2 scientist-years. It is involved in:

- conducting resource inventories in cooperation with Island governments;
- testing native and introduced tree species, especially nitrogen-fixing trees;
- developing silvicultural methods for reforesting understocked savanna uplands and deforested coastal areas, thereby increasing protection and use of critical watersheds, and/or for timber production;
- publishing a nontechnical handbook on forest reestablishment;
- selecting, establishing, protecting, and using natural areas;
- analyzing performance of selected coconut varieties on tropical islands and atolls;
- studying potential for sustained-yield management of the indigenous fruit bat; and
- developing cultural practices to maximize yields of selected agroforestry crops (31,39).

As the U.S. Trust Territory of the Pacific Islands government infrastructure is dismantled, the Research Work Unit is developing close working relations with the extant and emerging governments in American Samoa and Micronesia. More personnel and funding will be required to make the best use of this institution.

Technology Transfer

Forestry extension agents and activities in Puerto Rico and the U.S. Virgin Islands are few. Although there are a number of field agents who advise landowners on land-use alternatives in the U.S. Caribbean (Department of Natural Resources, U.S. Soil Conservation Service, and U.S. Agricultural Extension Service agents), few have been trained in forestry. Field agents have little incentive to seek this training because they typically are responsible for many areas of extension and little of their time is devoted to forestry. Rural landowners must rely on the extension and media activities of the Puerto Rico DNR and the ITF to become informed of techniques and available incentives.

One U.S. Forest Service person is responsible for State and Private Forestry in Puerto Rico and the U.S. Virgin Islands. He helps the Puerto Rico DNR apply for U.S. Forest Service grants and coordinates U.S. participation in the Cooperative Forest Management Act. This act allows the U.S. Forest Service to cooperate with the DNR to promote reforestation and protection of public and private lands (14). There also is only one person assigned to State and private forestry activities for Hawaii and the western Pacific.

The forestry agencies in the western Pacific do not have organized extension services. Distances between islands compound the problems of devising technologies appropriate to the area and people. Scientists and technology developers usually can visit only a few islands.

Opportunity: The U.S. Forest Service could support Puerto Rican forestry programs through increased State forestry grants. These grants seem an effective means of stimulating the Commonwealth Forest Service to support, coordinate, and demonstrate desirable forestry practices. The flexibility and individuality of the State grant program allow specific application of funding to U.S. Caribbean problems. This would require increased personnel for the U.S. Forest Service State and Private Forestry in Puerto Rico. Foresters from the United States who are experienced in aiding State forestry organizations can be effective in advising on nursery operations, logging techniques, use strategies, genetic improvement programs, research needs, extension practices, and other elements of program development.

Congress has made special allowance for the Peace Corps to operate in the U.S. Trust Territory, at least until the Compact of Free Association is signed. These volunteers could provide a means for technology transfer and for feedback to researchers regarding needed adaptations of technologies. The Peace Corps could ensure that all its rural volunteers have at least some forestry training and are in contact with the appropriate agencies for technical aid.

A cadre of local, "grass-roots" naturalists could be created in the U.S. western Pacific with help from the U.S. Forest Service, Department of the Interior, Peace Corps, and island governments and universities. Such a program could provide general training that would qualify participants to assist both permanent and visiting research scientists. They could help spread information on appropriate land uses and help integrate new technologies with local customs (38).

CONCLUSION

If tropical forest resources are to be sustained in the U.S. territories, indigenous resource management organizations must be strengthened. Because these governments are still heavily reliant on U.S. assistance and their resource agencies are in their infancy, the United States retains a substantial role in developing both the agencies and resource-sustaining technologies.

In the short run, U.S. technical assistance is needed to design forest management plans. In the long run, this assistance could be replaced by a skilled cadre of people trained in natural resource management at local institutions. Programs to encourage private forestry for each island probably will also require U.S. Federal assistance. The Federal institutions responsible for assisting forestry in the U.S. tropical territories are too small and their focus is too limited to give adequate impetus to local investment. More research and more forestry technology transfer are required, as is greater response to the changing needs of the territories.

Application of U.S. Expertise: U.S. expertise relevant to tropical forest resources is not used effectively in the U.S. tropical territories. This is partly because many experts consider the U.S. tropical territories a relatively insignificant part of the overall tropical forest resource conservation problem and partly because organizations that might be used to focus professional

expertise on the U.S. tropics do not have the necessary support to do so.

Definition of Roles in U.S. Western Pacific: Resource development planning in the western Pacific territories is constrained by a lack of definition of the respective roles of local, U.S. Federal, and international organizations. Little analysis and no decisions have been made on the question of whether the authority of the U.S. Federal agencies is adequate or appropriate to serve the resource needs of Micronesia and American Samoa (29). In particular, with the political changes in the region, applicable Federal programs must be identified and directed toward island needs. Under new agreements with territory governments, U.S. support is planned to be offered primarily in cash rather than through Federal categorical programs, although room is left for extension of agreed-upon programs (34).

The Interagency Task Force on U.S. Territories* could conduct a comprehensive review of Federal legislation applicable to natural resource use in the western Pacific area. This effort could identify legislation needed to support sustainable natural resource development. It also could identify alternative ways to implement legislation that would both sustain the resources and achieve the goals of the agencies (29).

Local Resource Agencies: Opportunities exist to use forest-resource sustaining technologies in western Pacific territories. The territorial governments all have designated natural resource agencies with a forestry component. But these agencies are relatively new and do not yet have adequate funding, professional personnel or policies to take full advantage of the opportunities.

Political support for the natural resource agencies seems to exist. However, there has been very limited planning for the forested areas. In practice, some forestry has concentrated on nursery planting and extension without operational plans or assignment of responsibility (4). without more outside assistance, development is likely to proceed so slowly that needed resource productivity and economic opportunities will be lost.

The Federal Resources Planning Act of 1974 (RPA) as amended, the Cooperative Forestry Assistance Act of 1978, and other recent legislation have extended the prospects of Federal forestry assistance to Pacific islands. The U.S. Forest Service could increase aid to territorial governments in developing natural resource agencies, provide technical assistance for resource assessments, help develop policies, management, and enforcement plans, and provide technical assistance for implementation.

Private Forest Investment Programs: Programs designed for the U.S. continental States to promote soil and water conservation and private reforestation usually do not apply well to tropical island characteristics. For example, small landholding size, low income, and lack of technical knowledge prohibit many rural landholders in Puerto Rico from participating in reforestation.

Because the U.S. tropical territories are so different from the 50 States—politically, economically, culturally, and ecologically—investment incentive programs designed for the States are unlikely to be effective in the islands. And because the territories are themselves heterogeneous, a single program probably cannot be designed to be effective on all islands. An alternative is to make funds and technical assistance available to private investors through individual territorial governments.

Congress could create a reforestation incentives program that could: 1) be operated jointly by the U.S. Forest Service and the territorial governments, 2) be designed specifically for local characteristics, 3) be integrated with other natural resource development objectives, 4) include agroforestry and/or an annual loan to provide early income before harvest, and 5) encourage organization of forestry cooperatives. More generally, Congress could analyze all legislation involving proposed or actual natural resource programs that might be applicable to

*The Interagency Task Force on U.S. Territories includes representatives from most Federal agencies, including Housing and Urban Development, Health and Human Services, Education, Defense, Commerce, Interior, Agriculture, and the Environmental Protection Agency. It is housed under the Department of the Interior's Office of Territorial and International Affairs.

the U.S. territories and write in language ensuring applicability to the needs of the territories (20,25). Alternatively, it could create complementary but different natural resource conservation and use programs designed specifically for the characteristics and needs of the territories.

U.S. Forest Service Institutes located in Puerto Rico and Hawaii are assisting the territories in developing technologies and institutions to sustain tropical forest resources. However, both institutes have too few staff and budgets that are small and declining. They cannot support the scale of development activity necessary to sustain the U.S. tropical forest resources. If the institutions are given further responsibilities in international forestry without new funding and personnel, their effectiveness will be diminished.

CHAPTER 13 REFERENCES

1. Beard, J. S., "Climax Vegetation in Tropical America," *Ecology* 25:127-158, 1944. *In*: Schmidt (19).
2. Beard, J. S., "The Classification of Tropical American Vegetation-types," *Ecology* 36:89-100, 1955. *In*: Schmidt, (19).
3. Bough, E. L., Director, Forestry Program, U.S. Virgin Islands Department of Agriculture, personal communication, 1983.
4. Clayton, R., "National Progress Report on Forestry for Pacific Islands (USA)," prepared for the Asia-Pacific Forestry Commission, Eleventh Session, January 1981.
5. Emmons, B. R., "Forestry in Micronesia," Division of Agriculture, Department of Resources and Development, Trust Territory of the Pacific Islands (available at the Forestry Library, Ponape), 1971.
6. Falanruw, M. C. V., "Study Plan: Ecology and Management of the Fruitbats of Yap," U.S. Forest Service Pacific Southwest Forest and Range Experiment Station, Institute of Pacific Islands Forestry, Honolulu, Hawaii, 1979.
7. Hess, A., "The Forestry Incentives Program in Puerto Rico," The Johns Hopkins University, Public Policy Program, thesis, 1982.
8. Holdridge, L. R., *Life Zone Ecology*, Tropical Science Center, San Jose, Costa Rica, 1967. *In*: Schmidt (19).
9. Holdridge, L. R., Crenke, W. C., Hathaway, W. H., Liang, J., and Tosi, J. A., *Forest Environments in Tropical Life Zones, A Pilot Study* (Oxford: Pergamon Press, 1971). *In*: Schmidt (19).
10. International Union for Conservation of Nature and Natural Resources (IUCN), 1982 *United Nations List of National Parks and Protected Areas*, Gland, Switzerland, 1982.
11. Johnson, S. P., "Palau and a Seventy Islands Tropical Park," *National Parks and Conservation Magazine* 46(4):12-17;(7):4-8;(8):9-13, *1972*.
12. Krochmal, C., "Identification and Development of New Tropical Forest Resources in Puerto and the U.S. Virgin Islands," OTA commissioned paper, 1982.
13. Lambrecht, F. L., "Development and Health in the Tropics, Part 1: West Africa," paper prepared for AID, Arid Land Study Office, University of Arizona, no date.
14. Liegel, L. H., "Woodland Conservation in Puerto Rico: Its Past, Present and Future," New York College of Environmental Science and Forestry, Syracuse, N. Y., thesis, 1973.
15. Owen, R. P., "Remarks Concerning Tropical Forests in Micronesia," personal communication, Jan. 6, 1982.
16. Pico, R., *The Geography of Puerto Rico* (Chicago: Aldine Publishing Co., 1974).
17. Philpot, C. W., "An Administrator's Look at Programs in the Pacific Islands," *Moving Forestry and Wildlife into the 80's*, Proceedings of Hawaii Forestry Wildlife Conference, USDA Forest Service, Honolulu, Hawaii, 1982.
18. Richardson, D., "Coconut Charcoal Could Fuel Ships," *Pacific Islands Monthly*, May 1981.
19. Schmidt, R., "Forestry in Puerto Rico and the Virgin Islands," OTA commissioned paper, 1982.
20. Schmidt, R., "Forestry in Puerto Rico," *Forestry in the Caribbean*, U.S. Man and the Biosphere Program, 1982.
21. Schmidt, R., Director, Forest Service, Puerto Rico Department of Natural Resources, personal communication, 1982.
22. Schmidt, R., personal communication, 1983.

25-287 0 - 84 - 20

23. Somberg, S. I., "Virgin Islands Forestry Research: A Problem Analysis, " College of the Virgin Islands, Virgin Islands Agricultural Experiment Station, St. Croix, U.S. Virgin Islands, Report No. 9, 1976.
24. Swiderski, J., "Small-Scale Forest Industries for Developing Countries," FAO position paper prepared for the Eighth World Forestry Congress, Jakarta, Indonesia, Oct. 16-28, 1978.
25. Towle, E., Island Resources Foundation, St. Thomas, U.S. Virgin Islands, personal communication, 1983.
26. U.S. Bureau of the Census, "1978 Census of Agriculture" (Washington D. C.: U.S. Government Printing office, 1980).
27. U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, "Forestry Incentives Program: From Inception of Program Through September 30, 1980" (Washington, D. C.: U.S. Department of Agriculture, 1980).
28. U.S. Department of Agriculture, Soil Conservation Service, ***Soil** Survey of Puerto Rico* (Washington D. C.: U.S. Government Printing Office, 1942). ***In:*** Pico, *1974*.
29. U.S. Fish and Wildlife Service, ***The Pacific Islands: The Challenge of the 1980's,*** Department of the Interior, U.S. Fish and Wildlife Service, Region 1, Portland, Oreg., 1978.
30. U.S. Forest Service, Institute of Tropical Forestry, "Annual Letter: 1981," U.S. Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Rio Piedras, Puerto Rico, 1981.
31 U.S. Forest Service, Institute of Pacific Islands Forestry, "Pacific Islands (Territories) Forestry Research Unit," Pacific Southwest Forest and Range Experiment Station Publication No. 1252, Honolulu, Hawaii, 1981.
32, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, "International Forestry Plan for Oceania, Asia, and Western Pacific," U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif., 1980.
33 U.S. General Accounting Office, ***The Challenge of Enhancing Micronesia Self-sufficiency*** (Washington, D. C.: U.S. General Accounting Office, 1983).
34 U.S. Congress, U.S. Senate, Energy and Natural Resources Committee, "Oversight Hearings of Micronesia Political Status Negotiations, June 3, 1980" (photocopy).
35. Wadsworth, F. H., "Timber," ***Conceptos, plan y programa para una agricultural moderna en Puerto Rico,*** J. Vicente-Chandler Special Report to the Secretary of Agriculture of Puerto Rico, 1978, pp. 325-340. ***In:*** Schmidt (19).
36. Wadsworth, F. H., "Timber and Forest Energy Development Potentials for Puerto Rico," 1982, ***Symposium on Biomass Production in Puerto Rico*** (in preparation). ***In:*** Schmidt (19).
37. Weaver, P., "Agri-silviculture in Tropical America," *Unasylva* 31(126):2-12, *1979.*
38. Whitesell, C. D., Philpot, C. W., and Falanruw, M. C. V., "Congressional Action to Improve the Sustainability of U.S. Tropical Forests in the Pacific," OTA commissioned paper, 1982,
39. Whitesell, C., U.S. Forest Service, personal communication, 1983.
40. Whitmore J. L., and Liegel, L, H., "Spacing Trial of *Pinus caribaea* var. *hondurensis*," U.S. Forest Service Research Paper SO-162, Southern Forest Experiment Station, New Orleans, La., 1980.

PART III
Options for Congress