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Montane Forest Management in the Insular Caribbean

Frank H. Wadsworth

Cover photograph: An opaque canopy over the soil characterizes these primary moist forests in the mountains of Puerto Rico.

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Abstract

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Two elevations—above 800 m and above 300 m—define the montane forests of the Caribbean islands. Of the 36 islands considered, 27 have mountains above 300 m and 14, above 800 m. Of the 233,000 km^2 of the islands, at least 118,000 km^2 are above 300 m, and 60,000 km^2 are above 800 m. At least 20,000 km^2 above 300 m and 10,000 km^2 above 800 m are covered by forest. Significant areas of montane forests have been legally reserved, with at least protective management on the larger islands. An ambitious, community-oriented, multiple-forest land-use program has been under trial for many years in the Dominican Republic. Silvicultural practice for timber production is limited largely to plantations; at best, yields are promising. Further research and strengthening of public policies and forestry programs are needed throughout the region.

Keywords: Caribbean, forests, mountains.

Contents

Introduction

The Forestry Department of the Food and Agriculture Organization of the United Nations, having reviewed the management of forests in tropical Asia (Anonymous 1989b), the moist tropical forests of Africa (Anonymous 1989) and tropical Latin America (Anonymous 1993), and the management of mangroves (Anonymous 1994), has initiated a document on managing montane forests. This paper, a supplement to the others, is about the montane forests on the islands bordering the Caribbean Sea.

Definitions

Because four key terms are critical for understanding the information presented, I include these definitions:

The Caribbean here considered is limited to the Greater and Lesser Antilles. Excluded are the continental areas of Central America and northern South America bordering on the Caribbean.

Mountains, as defined by FAO, are areas 800 meters above sea level. Only small areas of the Caribbean islands exceed that elevation, however. Because most of the forest management practiced in our region has been on slopes at elevations below 800 m, I have used a second elevational minimum of 300 m above sea level for this review. Reported differences between forests and forestry at these two elevations are presented.

Forests are defined by FAO as lands covered 10 percent or more by natural or planted trees and not used primarily for some other purpose. Lands dedicated to forest products are emphasized.

Management, for FAO purposes, is protection plus cultural treatment related to the productivity of forests. In much of the region, manipulating mountain forests to further their productivity has not yet been conclusively tested. This report therefore dwells on the background, a description of the mountain areas, existing forests and their use, protective steps taken and their effectiveness, and efforts to stimulate forest productivity.

Sources of information

My primary source of information has been the library of the International Institute of Tropical Forestry. There, among numerous country reports, are key publications of FAO (Anonymous 1990a), the Caribbean Development Bank Sector Reviews (Anonymous 1983), the Country Environmental Profiles (Anonymous 1987-1991), and the Tropical Forestry Action Plans for the islands (Anonymous 1990-1993). I also drew on the research files of the Institute, including the unpublished results of local studies. Additional sources were the technical library of the Island Resources Foundation, St. Thomas, and the Caribbean Natural Resources Institute, St. Croix, in the U.S. Virgin Islands. An important general source on the forests of tropical America is Harcourt and Sayer (1995).

To supplement written sources, I consulted the staff of the IITF most familiar with the Caribbean, particularly Peter L. Weaver and Carleen Yocum. In addition, I visited the Dominican Republic (José Martínez Guridi of Pronatura, José Elías González of Plan Sierra, and Constanza Casanovas of the Dirección Nacional de Parques), Jamaica (Roy Jones, Conservator of Forests), Guadeloupe (Jacques Portecop of the Université des Antilles et de la Guyana and Isebelle Bracco-Sabbulet of the Office des Forets), and Trinidad (Fred Singh of the Forest Department and Claus-Martin Eckelmann of the Subregional FAO Office).

A deficiency is the lack of up-to-date information on Cuba and Haiti, but access to both countries was impractical. Reports of forest research from Cuba indicate an active technical program there. Reports from Haiti are chiefly those of nongovernmental organizations doing reforestation and agroforestry.

Background

Mountain areas

Few local public policies focusing on “mountains,” as here defined, have been found. Exceptions are in St. Kitts, Montserrat, and St. Vincent, where Crown or private lands above a specified elevation, according to ordinances now very old, were to remain or return to forest, and the “Plan Sierra” of the Dominican Republic. The lack of references elsewhere to elevation denotes a remarkable lack of sensitivity to the great significance that mountains have to life on most of the islands of this region. Even determining reliably how much of each island lies above the 300- and 800-m contours has been difficult. Available data are presented in geographical order, progressing clockwise from Cuba to Aruba, in table 1.

The mountains

Mountains are extensive in only 16 of the 36 islands, but that does not mean that uplands are unimportant on the others. Useful information on forest management exists only where the mountains are extensive.

The mountains are generally described as steep, and landslides occur even beneath closed natural forest (Lackhan 1980). In Jamaica and St. Lucia, 50 percent of the land is reported to be steeper than 20° (Anonymous 1993); in Haiti, 63 percent of the land is that steep (Anonymous 1991b). A common erosion-control recommendation for the region is to retain permanent vegetative cover on slopes in excess of 30° (Miller and others 1988).

The mountains of the Caribbean islands contribute more to cloudiness and rainfall at high elevations than at lower elevations. Virtually all of the mountainous areas of the islands receive at least 200 cm of rainfall annually; an exception is above the cloud base in the highest mountains of Hispaniola. In Martinique and Guadeloupe, mean annual rainfall on the peaks is estimated to reach 800 cm. One result is that Basse Terre, Guadeloupe, at the base of the mountains is one of the few cities of the region with no critical water-supply problem. The mountains of the Northern Range of Trinidad are reported to yield a significant portion of the water supply of the entire country (Anonymous 1990b). In the smaller islands, this dependence on water from forests is nearly total because groundwater supplying the wells on the coastal plain is largely what has percolated through the porous forested soil of tributary mountain slopes.

Worthy of special appreciation are the elfin cloud-forest ecosystems of the larger islands (Scatena 1994). An area of 226 ha of such forest above 800 m in Puerto Rico is estimated to be worth billions of U.S. dollars for its strategic, investment, water, research, and recreational values. Particularly significant are its lack of substitutability as an island resource and the resultant irreversible nature of its exploitation.

The forests

A mimimum estimate of the existing forest cover on the mountainous islands appears in table 2. But before human intervention, the mountains of the islands were, with minor exceptions, forest covered. Even in the savannas of Martinique above 1,000-m elevation and in the Soufriere of Guadeloupe, stunted woody plant species are colonizing the land (Anonymous 1992a). Average tree height responds to elevation: trees grow up to 9-18 m below 800-m elevation, and 4 to 9 m above (Anonymous 1982). At 1,700 m on St. John’s Peak in the Blue Mountains of Jamaica, the forest canopy is 5 to 10 m above the ground (Bronckers and van Hesteren 1995). With the exception of

Table 1—Caribbean island and mountain areas[a]

Island	Total land area	Mountain area	
		>300 m	>800 m
		km²	
Cuba	111,000	(55,700)	22,500
Cayman Islands	260	0	0
Jamaica	11,500	5,600	1,500
Haiti	27,700	(17,700)	11,800
Dominican Republic	49,500	36,000	20,800
Puerto Rico	8,970	(5,440)	3,330
St. Thomas	83	3	0
St. John	51	1	0
St. Croix	233	3	0
Tortola	54	3	0
Virgin Gorda	21	3	0
Anegada	34	0	0
Anguilla	90	0	0
St. Martin	85	4	0
St. Barthelemy	15	0	0
Saba	13	2	0
St. Eustatius	21	7	0
Anegada	39	0	0
St. Kitts	176	49	21
Nevis	130	68	32
Antigua	282	4	0
Barbuda	163	0	0
Montserrat	83	28	1
Guadeloupe	1,780	202	45
Dominica	790	355	118
Martinique	1,100	245	40
St. Lucia	616	96	2
St. Vincent	388	81	28
Barbados	430	7	0
Grenada	344	74	0
Tobago	303	41	0
Trinidad	4,820	228	10
Margarita	1,070	(120)	0
Bonaire	287	0	0
Curacao	471	0	0
Aruba	179	0	0
Totals	223,081	117,564	60,227

[a] These figures come from a variety of sources, including the Encyclopedia Britannica, Webster-Merriam Geographical Dictionary, FAO Forestry Paper 112 (Anonymous 1990a), and CCA/ECNAMP maps of the islands (Anonymous 1980b). The figures in parentheses are estimates, where adequate contour maps were not available. Except where some better source was found, these data were derived by assuming arbitrarily that 3/8 of the land below 800 m is above 300 m.

Table 2—Minimal forested area on mountainous islands[a]

Island	Estimated forest cover >300 m	Estimated forest cover >800 m
	km^2	
Cuba	(10,400)	3,520
Jamaica	(1,200)	340
Haiti	(150)	110
Dominican Republic	(6,250)	4,630
Puerto Rico	(1,990)	1,190
St. Kitts	(20)	(10)
Nevis	(20)	(10)
Montserrat	(10)	(0)
Guadeloupe	(110)	(20)
Dominica	(200)	(60)
Martinique	(90)	(10)
St. Lucia	(10)	(0)
St. Vincent	(20)	(10)
Grenada	(10)	(0)
Trinidad	(60)	(10)
Margarita	?	?
Totals	20,540	9,920

[a] The parenthetic values were derived mostly by applying area figures for nationwide forests and plantations (Anonymous 1990a) as a percentage of total land area to the mountain areas of table 1. These figures should be conservative because the mountains tend to be more covered with forest than is the rest of the land. They have also been rounded downward to the nearest 10 km^2. Reliable data could not be obtained for Margarita (Anonymous 1978). The totals indicate minimal values, so forests cover at least 16 percent of the mountains.

the pine forests of eastern Cuba and some 300,000 ha in upland Hispaniola (Morell 1986, Anonymous 1990-1993), all of the mountain forests of the islands are of mixed broadleaf tree species. Even in the mountains of Hispaniola, at least 30 percent of the pine forests are mixed (Hernández and Kemph 1984).

The widely used term “rain forest” does not apply to all of these forests. Above 600 m, the forest may be pine, montane thicket, palm brake, or elfin woodland (in accordance with the ecological classification system of Beard 1949).

Insularity has led to high endemism among the plant and animal species. Reportedly, fully 50 percent of the plant species in Cuba are endemic (Samek 1973). Corresponding figures for Hispaniola are 37 percent; Jamaica, 20 percent; Puerto Rico, 13 percent; the Lesser Antilles, 10-12 percent; Trinidad and Tobago, 7 percent; and Bonaire, Curacao, and Aruba, 5 percent. The island of Dominica has 42 tree species endemic to the region; Montserrat, 17 species; and Grenada, 15 species (Miller and others 1988). Some of the forest vertebrates—parrots, for example—are also endemic; in Jamaica, 23 percent of the resident bird species are endemic (Anonymous 1983). Many of the bird species of the islands, such as the Puerto Rican parrot, are threatened with extinction (Anonymous 1983, Miller and others 1988).

Forest use

The use of the mountain forests of the islands stems almost totally from the arrival of Europeans and their followers. The most significant use has been agriculture. Haiti is an extreme case, with farming on more than 99 percent of its mountains (Anonymous 1991b). In Puerto Rico, although the island now is more than 33 percent forested, less than 1 percent is primary forest; the rest was modified or cleared in the past (Wadsworth 1949). Even in St. Vincent, only 5 percent of the land retains primary forest (Miller and others 1988). In Montserrat above 1,000 m, all of the primary forest has disappeared (Anonymous 1982).

On all of the islands—apparently except for Haiti, Puerto Rico, and Guadeloupe—net deforestation continues for agriculture. Even in the Dominican Republic, only 31 percent of the broadleaf forests were uncut by 1981 and, of the pine forests, only 28 percent remained (Anonymous 1990a). About 379,000 ha of forest disappeared in the Dominican Republic during the 22 years before 1986 (Morell 1986). Alternatives to agriculture specific to Puerto Rico have lowered but not entirely removed pressures to convert forested lands to other uses. In Haiti, where reportedly 63 percent of the land is too steep to be cultivated sustainably, deforestation has reached virtually the maximum possible, with 40 percent of the land denuded, severely eroded, or completely sterile (Anonymous 1991b). In Jamaica, 19 of 33 major watersheds have been degraded by soil erosion, yet deforestation reportedly continues at a rate of 3.3 percent annually (Lackhan 1992). In the Northern Range of Trinidad, deforestation is reportedly proceeding at a rate of 300 ha per year, causing flash flooding, sedimentation, and irregularity of streamflow (Lackhan 1992). Forest clearing in the mountains there is said to produce 10 to 40 tons of soil loss per hectare per year (Anonymous 1987-1991).

Agricultural development has passed much of the mountainous land from public to private ownership, particularly in Haiti, Puerto Rico, Nevis, and Montserrat (Anonymous 1990-1993). Islands with much of their mountain land still in public ownership include Jamaica, St. Kitts, St. Lucia, Dominica, St. Vincent, and Grenada (Anonymous 1990-1993).

Next to soil, water has apparently been the most generally used product of the islands' forests. In Dominica, 90 percent of the electric energy is hydro-generated. In 1984 in the Dominican Republic, 200,000 ha were in irrigated agriculture; in 1990, another 300,000 ha were considered suitable, many of them in deforested watersheds (Hernández and Kemph 1984, Anonymous 1990-1993).

Despite high rainfall in the mountains, size and steepness of watersheds limit water supplies, particularly during the least rainy months from February through April. Water-short periods with urban rationing are common on almost all of the islands. In Grenada, a 25-percent dry-season water deficit is considered normal; St. Vincent's is 50 percent (Anonymous 1993). On some islands, the public perceives water scarcity as inevitable, which augers poorly for support of many possible measures for improving water availability.

The forests of the mountains became a prime source of useful wood as suitable trees at lower elevations became scarce. As early as 1620, the gommier and magnolia of the mountains of Martinique began to be exported (Anonymous 1992b). Wood preference has been for three properties: durability, workability, and appearance. The largest and best trees of a few preferred species were removed. As long as more mature timber remained farther up the mountain, cutover forests have been considered worthless, and—even today—they continue to be eliminated for subsistence or cash-crop agriculture.

As forest exploitation progressed up the slopes, wood cutters encountered less usable timber, except in the pine forests of Hispaniola and Cuba, because the montane thicket, palm brake, and elfin woodland forest types of most islands contain few trees wanted for their wood. The inventory of forests between 300- and 600-m elevation in Martinique showed that nearly 40 percent of the volume was of little-used species. Increasing scarcity of local wood led to import substitution, with all of the islands now heavy importers of woods more uniform and better manufactured than local products. Even in well-forested Dominica, the furniture industry, based initially on local timber, imports mahogany and other Brazilian woods. Wood and paper products today make up 10 percent of Dominica's imports (Anonymous 1983).

Posts and fuelwood are still provided locally in the islands. For much of the population, no economical alternatives to wood fuel or charcoal for cooking are foreseeable. In Jamaica, 37 percent of the households cook with charcoal. In Grenada, fuelwood is used in 51 percent of the households and charcoal in 75 percent (Miller and others 1988). In St. Vincent, 80 percent of the population use wood or charcoal (Anonymous 1990-1993); in Haiti, it is 96 percent (Anonymous l991b). The consumption of fuelwood and charcoal in the Dominican Republic in 1990 was estimated at 3,900,000 m^3 annually, or more than half a cubic meter per capita (Anonymous 1990a). Another 1,100,000 m^3 per year is consumed in the English-speaking islands of the Caribbean (Lackhan 1992).

Exploitation of forests for posts and fuel leads to deforestation because almost every tree can be used for these purposes. Yet the fuelwood market is a potential blessing; if removal is limited to only the trees least promising for more valuable products, then this thinning could encourage increased productivity of the remaining forests.

The wildlife of these islands, indigenous to the former forests, has been significantly reduced. Habitat destruction by deforestation, as well as hunting, have exterminated several species of birds and amphibians. As with the more useful trees, some mountain animal species show habitat preferences for the lower slopes more subject to deforestation and hunting (Shanks and Putney 1979, Evans 1988).

The forested mountains of the islands have, until recently, largely escaped effects of human appreciation. An early development was the building of mountain hotels in the Dominican Republic, but there the emphasis was largely on just escaping the heat of the lowlands. Foot trails to the high peaks and waterfalls have existed on most islands throughout this century. The recent influx of tourists has led to unprecedented developmental investments in nearly all the mountainous islands. In Puerto Rico, St. Lucia, Grenada, Martinique, and Guadeloupe, attractive roads and even guided tours lead to beauty spots in the mountains (Miller and others 1988). The visitors create a demand for natural forests with spectacular native trees and visible wildlife.

Use of island forests has not been limited to the local population and the recreational visitors. Organizations in the region that have made studies of the forests include the Forest Department of Trinidad, the University of the West Indies, the International Institute of Tropical Forestry, the Island Resources Foundation, the Caribbean Natural Resources Institute, the Organization of American States, the Caribbean Development Bank, and the Caribbean Conservation Association. Many of these institutions have been supported from outside the region by universities and bilateral governmental programs, notably from the United Kingdom, Canada, the United States of America, France, Germany, the Netherlands, and Sweden, and multinational sources, such as the United Nations, the Interamerican Development Bank, and the World Bank. More has been learned about the forests of these islands than is being applied in their management.

Forest protection

Forest management, by definition, is founded on an assumption that the diverse resources of the forest are being protected. Therefore, the status of forest protection in the islands deserves full exposure. I have attempted to show the legal situation related to protecting the mountain forests of the islands in table 3. The information was derived from various sources and may not be entirely correct.

The table shows only the islands where legal designation has progressed. Some of them may have been unintentionally omitted, and some of the designated areas may not be entirely within the mountains as here defined. An attempt to present the number of hectares designated in each island for each category was abandoned when I found that figures from different sources varied markedly and concluded that, in any event, the size of each legally designated area would contribute little to the present analysis, for reasons presented below.

The fact that an island has a legally designated mountain forest area should not be interpreted as adequately protecting the land. The designated reserves are but small fractions of the mountain lands described as too steep for sustained agricultural use. In most of the islands, the boundaries of legally established reserves have not even been marked on the ground (Anonymous 1983, Miller and others 1988). Furthermore, in at least Jamaica, Puerto Rico, and Trinidad, some of the forests once legally reserved have since been lost.

Table 3—Islands with legally designated mountain forests

Island	Primarily for preserving water, biodiversity, or esthetic values	Primarily for protective use and production
Cuba		+
Jamaica	+	+
Haiti	+	
Dominican Republic	+	
Puerto Rico	+	+
St. Kitts		+
Nevis		+
Montserrat		+
Guadeloupe	+	+
Dominica	+	+
Martinique	+	+
St. Lucia		+
St. Vincent	+	+
Grenada		+
Trinidad		+
Margarita	+	+
Totals (minimal)	>300,000 ha	>500,000 ha

In none of the islands has all public land probably best suited for forests been so designated. In Dominica and Grenada, thousands of hectares of Crown Lands in the mountains have not been consolidated with the designated public forests (Miller and others 1988). Even in Puerto Rico, where reserves were legally established beginning in 1876, the reserves today cover less than 10 percent of the land area least suited for nonforest uses, and large areas of lands needing forest protection are administered by government agencies other than the Forest Services for purposes inconsistent with forest conservation. And even designated State Forests are subject to invasion, almost at will, by the government itself for public works like highways and power transmission.

An added source of uncertainty about legal designation arises from the long period between initial recommendations and official action. An example is the Blue and John Crow Mountains National Park in Jamaica, recommended repeatedly for several years before its final approval in 1993. A similar period preceded the acceptance by UNESCO of a large Biosphere Reserve in Cuba. Moves to establish National Parks have long been proposed for Monserrat (Ford 1988). An announcement that forest reserves are to be established in St. Kitts was made in 1991, even though a forest ordinance in 1904 reserved all lands then forested (Miller and others 1988, Anonymous 1991a).

A further source of uncertainty in interpreting table 3 is the local meaning of “reservation.” Some of the earliest reserves, such as the Crown Lands of St. Kitts, Nevis, Montserrat, and St. Vincent (Miller and others 1988), required only retaining forest cover, apparently without constraint on partial timber harvesting. In Puerto Rico, after Crown Land “reserve” was established in the Luquillo Mountains, land concessions in the reserve were made by the Spanish government. Few of the areas designated as National Parks (shown in the first column of table 3) purport to prohibit all use except recreation or research. Thus, some may differ little from the forest reserves in the second column, more openly available for extractive uses.

Another weakness is that, at the time of designation, most reserves already had long-established private occupancy which has neither been eliminated nor even contested. In St. Lucia and St. Vincent, even the legal definition of Crown Lands is debated (Anonymous 1987-1991). The legal basis for evicting long-term occupants, even those without valid land titles, is questionable in some islands. Public protection of forests on private lands, as has been authorized in Montserrat, St. Lucia, and St. Vincent, has not been effective (Miller and others 1988). Eviction of private occupancy from designated forests has been neither politically popular nor financially feasible where repurchase would be required. Reclaiming former public lands by the government, as was done long ago in Jamaica, and their repurchase, as in Puerto Rico, have essentially ceased.

All the mountainous islands have governmental conservation agencies, mostly Forest Departments, but some, such as Jamaica and Guadeloupe, have separate administrations for National Parks. In Guadeloupe, Martinique, Dominica, St. Lucia, and Grenada, the control of all Protected Areas, as well as soil, water, and wildlife conservation and forest recreation development are also responsibilities of Forest Departments (Miller and others 1988, Anonymous 1991a). Yet neither official forest policies, legislation, repeated comprehensive planning, nor the programs of public education about forest values and the importance of conservation—which are active in all of the islands—have served everywhere to stabilize land use and reserved forest boundaries (Hernández and Kemph 1984).

Except in Puerto Rico, Guadeloupe, Martinique, and possibly Cuba, the protective personnel are either too few or they are inadequately supported to prevent deforestation. Occupancy trespass is particularly serious in densely populated Jamaica and Trinidad, both of which have long-standing, officially ratified forest policies calling not only for protecting the designated public forests but also for relying on producing forest products needed in the future from them. The other mountainous islands all have far fewer forest guards than Jamaica and Trinidad, and those in St. Kitts and Nevis may still be only part-time employees (Anonymous 1983). In Trinidad, the Forest Department may proceed legally against any person found actually felling government-owned trees in an area identifiable as a declared public forest, but the authority to evict such trespassers rests with another agency, a critical loophole in forest protection. Thus, despite policies, legislation, and a protective force, misuse of the legally reserved mountains of most of the islands continues.

With such ineffective conservation of forests in public ownership, we should not be at all surprised that—with few exceptions, such as in St. Kitts and Nevis—forests have not been conserved effectively on privately owned lands either. In St. Lucia, a Forest Development Plan called for preserving rain forest on private lands but provided no means to motivate landowners to comply (Miller and others 1988).

Timber Production from Natural Forests

A rationale for natural-forest timber production

The need for forest production on these islands, taken for granted in past public policies, legislation, and reservations, has come under close scrutiny recently because of fundamental changes in the social and economic development of the resident human communities.

Forest intervention short of deforestation for agriculture on these islands has so far been concerned almost totally with the harvest of trees for their wood. Effects of timber operations on the soil, water, nutrients, and the forest fauna have hardly been seriously assessed, but adverse consequences have become obvious. A result is a growing public perception that timber harvest may simply be incompatible with preserving the other native forest resources. This perception raises a question as to whether timber harvest (and therefore production) should be excluded from critical watershed lands and rare wildlife habitat. One extreme viewpoint is that the exclusion of all human intervention is the only way to preserve these other values. Arguably, however, scientifically guided and carefully controlled forest manipulation may be both tolerable and desirable for each of these values, and an optimum degree of modification may exist that benefits them all.

The purpose for preserving and managing forests on the mountains of these islands, however, has never been solely for any one value. Wood was needed for building, various forest plants yielded useful fibers, the hunted birds were concentrated in the forests, and so were the sources of good water. More recently, forests have been used as sites for electronic communications. Because these resources came from the lands least attractive for other purposes, forests have been seen as a supplement to other, “more profitable” land uses on other lands.

With these as underlying justifications for retaining forests, the isolation of the islands from other forests and the growing consumption of forest products led to policies to enhance the productivity of the forests primarily for local needs. Fuelwood and roundwood requirements have been supplied largely from lowland forests near the consumer. The mountain forests have been seen as a continuing source of the timbers they always have provided for construction and decorative cabinet woods, with fuelwood as a byproduct. Timber of mountain species such as *Cedrela odorata, Dacryodes excelsa, Manilkara bidentata,* and *Talauma dodecapetata* was even exported from the islands in the past.

Roundwood and fuelwood have made up the bulk of the local consumption of forest products, and their consumption may not be declining, but two circumstances challenge the premises of ordinances requiring that the island's forests are to meet future needs of the population. One arises from population growth; the remaining local forests, reduced in area, and mostly exploited or progressively less accessible and less well stocked, no longer are meeting people's current needs for high-value timber products. The other is the growth of commerce, bringing to the islands all but the least expensive forest products from external sources with advantages of scale, species diversity, and processing technology. This change has led to the transfer of local use and furniture manufacture from local to largely imported sawnwood and wood-panel products.

Even on islands where a market for the timber exists, concern is rising about felling mature trees in the mountains. With all the publicity about the unanticipated biodiversity values of unmodified tropical-forest ecosystems, the question again arises as to whether any further modification of the few primary forests—and even the better preserved modified and secondary forests remaining on these islands—is prudent, at least until the consequences are more fully understood. However legitimate this question is, stopping forest modification appears conjectural in the light of continuing forest intervention on these islands, despite both legislated reserves and publicly financed and assigned protective forces.

Perhaps a future role of the islands' forests should be their usefulness to, among others, the people who might otherwise misuse or destroy them. This usefulness presumably depends on a mix of products and other forest economic benefits for the neighboring communities, through gainful employment in educational, recreational, investigational, and commercial activities consistent with sustaining and optimizing the utility of the forest resources and their values. These benefits could present a rationale for producing wood in ways that meet these requirements. Making the forests sustainably produce high-value wood suitable for local processing should not be a difficult challenge technically in some areas, and it could contribute as much as other forest uses to the welfare of local communities. One of the highest uses of some of the woods is to support artisans capable of raising the value of the woods many-fold for the growing tourist markets of the islands.

Experience to date

Forest management that is more than purely protective has been almost entirely an activity of governments and within designated Forest Reserves. These forests, like others on the islands, have been subject to pressures arising from past and traditional uncontrolled use of trees on publicly owned land. Use has been constrained chiefly by lack of accessibility to the more remote mountain forests. Most of the trees have been considered suitable only for poles and fuelwood, neither of which has paid its way to distant roads or markets, so only the more accessible forests have been heavily used.

Policies, planning, and inventories

If forests are to be well managed, they must be subject to stable policies, long-term plans defining the location and integration of different forest uses, and reliable inventories to guide the process and practices. National forest policies have existed in some of the islands—such as Trinidad, Jamaica, and Dominica—for many decades (Anonymous 1983). Policy recommendations and revisions, made repeatedly for Montserrat, Dominica, St. Lucia, St. Vincent, and Trinidad and Tobago apparently still have not been adopted (Lackhan 1992).

This lack of progress emphasizes the need for comprehensive, long-term management planning. Plans approved by the highest government authority should justify—on both environmental and economic grounds—what is being proposed. They should be based on, or call for, an inventory of all resources of the forest, making possible the integrated conservation of each of them. Natural regeneration should be inventoried, as well as existing harvestable timber. Plans should describe needed transportation and specify precautions to minimize adverse effects of timber removal on other resources. They should define the desired productive forest structure and composition and treatments to achieve them. They should present a rational, if preliminary, prediction of increment and expected sustainable yields. They should recognize and emphasize pressing research needs. And they should show the size of the necessary budget.

Forest management planning has been initiated, completed, or even repeated in Jamaica, the Dominican Republic, Puerto Rico, Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, Grenada, and Trinidad and Tobago (Lackhan 1992). These plans have differed broadly, from mere expressions of conservation principles to the details of timber inventories, regulation of harvest, and silviculture (Anonymous 1992b). Compliance with established policies and plans is not widely evident, yet calls for more management plans and inventories are being heard throughout the islands (Anonymous 1993).

Plans for timber production on mountains must first be concerned with protecting the soil. Recommendations on several of the islands consider slopes in excess of 30° too subject to watershed damage for conventional road building or logging (Anonymous 1980a). This limitation would exclude timber production on 33,000 hectares of forested mountains in Trinidad (Anonymous 1980a). In Martinique, as much as 7,600 ha of forest has been identified as unsuitable for production (Anonymous 1992b). In Dominica, an even higher slope limitation of 40° in key watersheds, together with protecting critical wildlife habitat, would exclude timber harvesting from 50 percent of the Forest Reserves (Zamore 1992). Problems of timber accessibility and marketability reportedly would lower the average yield per hectare in the remaining area by another 50 percent. A report on Nevis states that the remaining forest areas are not suitable for sawtimber because of extreme slopes and the danger of erosion (Anonymous 1991a). Reports from Dominica and St. Lucia rule out tractor skidding because of the potential for erosion (Anonymous 1987-1991). Another points out that, even with alternative techniques for log breakdown at the stump and heading out the boards, many mountain roads would be needed (Zamore 1986).

Although comprehensive forest-management inventories are needed for all resources in the islands, they have so far been concerned chiefly with timber. Exceptions are the recent assessments of the natural history of southern Haiti (Woods and Ottenwalder 1992) and Jamaica's Blue and John Crow Mountains National Park (Muchoney and others 1994). Most of the forests have never been inventoried, but specific timber production areas have been inventoried in Jamaica, the Dominican Republic, Puerto Rico, Dominica, Guadeloupe, Martinique, St. Lucia, St. Vincent, and Trinidad and Tobago (Miller and others 1988, Anonymous 1992b). These inventories have varied in depth from mere searches for exploitable timber to detailed samples of trees of all species and sizes. Comparable inventories of other forest products or wildlife have not generally been carried out, although the vertebrate fauna have at least been identified.

An inventory of 3,700 ha of mountain forests in Martinique in 1974-75 showed clearly the importance of elevation to potential productivity of timber in the forests. The mean timber volume of the forests between 300- and 500-m elevation was 184 m^3/ha, but from 500- to 700-m elevation it was only 111 m^3/ha. For the primary timber species—*Dacryodes excelsa, Chimarrhis cymosa,* and *Simarouba amara*—the corresponding volumes at the two elevations were 91 and 27 m^3/ha, respectively. Even for *Talauma dodecapitata,* the respective volumes were 18 and 6 m^3/ha (Anonymous 1992b). The maps show that most land considered potentially productive of timber lies below 300 m.

Yield regulation

The first approach to regulating the timber harvest in reserved forests has been **area control,** which is assigning, for each year's harvest, an area of the forest that equals a corresponding fraction of the number of years in the rotation. In the Dominican Republic, Puerto Rico, Guadeloupe, and Martinique, this strategy has meant partitioning the forest area into compartments or "coupes" and assigning sequential treatments (Wadsworth 1957, Anonymous 1991c, Anonymous 1992a, Anonymous 1992b).

With or without area control, minimum girth or diameter has been imposed throughout the islands as a definition of tree maturity or readiness for harvest. The minima have generally ranged from 45 to 60 cm in dbh. In Jamaica, Puerto Rico, Guadeloupe, Dominica, and Trinidad and Tobago, the individual trees to be harvested have been designated by public forest officers (Lackhan 1992). The gradual opening of the forest by selectively removing overmature trees and reserving smaller ones has been assumed to assure another harvest in 15 to 40 years (Anonymous 1987-1991, Shanks and Putney 1979).

Sustained timber production over a given forest area requires that timber in an assigned area initially inaccessible because of remoteness will eventually become accessible. Road building has generally been a prerogative of different and independent government agencies, a fact that makes such an assumption uncertain. One result has been that accessible timber has been exploited at a rate that can be sustained only by the initially inaccessible timber. And now the extension of roads needed for the rest of the assigned timber production area, farther into the mountains, is subject to challenge on environmental grounds.

Harvesting

With only a few of the larger trees valued sufficiently to pay the costs of bringing logs roadside, harvesting just them alone has generally left most of the forest standing. Because the trees in reserves are usually sold on the stump, however, the governments have shown little concern with logging practices, a legitimate criticism of Forest Departments. The historical sequence in Puerto Rico was first wasteful pit sawing at the stump, and skidding of cants with oxen downslope, leaving incipient gullies. Then came tractors skidding whole logs, creating more serious uncontrolled erosion. In Dominica, mechanical logging enterprises have been submarginal, and they also dictate heavy cutting to justify the fixed and operating costs (Anonymous 1987-1991). Currently in Dominica and St. Lucia, logs are ripped at the stump with chainsaws and the boards headed out to the roads.

Postexploitation silviculture

Where minimum diameter limits have been observed and logging has not caused excessive damage, residual forests remain with promising trees for the future. Even in the forestry profession, however, an illusion persists that applying minimum-diameter limits alone leads to uniform periodic yields and even sustainability (Hernández and Kemph 1984). An examination of the structure of such cutover forests and the composition of their natural regeneration indicates the difficulty in achieving such uniformity soon (Anonymous 1992a). Sustainable polycyclic production will call for much cultural treatment of cutover forests to make them sufficiently well stocked and regular in structure to achieve this goal.

Managing cutover mountain forests, with exceptions in Guadeloupe, Martinique, and Puerto Rico, has been little more than protection. In at least Puerto Rico, Guadeloupe, Grenada, and Trinidad, stimulating secondary forests (cutovers and volunteers) has been attempted. On most islands, this strategy has not been tried on a large scale, somewhat paradoxically, because of a perception that the trees are growing too slowly. The much-heralded tropical shelterwood of Trinidad is at low elevation. In Grenada, secondary forest management is said to have been tried and failed (Lewis 1982, cited by Weaver 1989). Apparently, only in Guadeloupe and Puerto Rico have the composition and growth rates of the cutover forests been considered worth treatment. As a result, systematic silvicultural refinement of cutover mountain forests has been practiced on these islands, identifying crop trees and liberating them, to produce woods suitable for future markets.

In Guadeloupe, silvicultural selection of valuable tree species began in 1966 (Anonymous 1992a). As in Puerto Rico, *Dacryodes excelsa* withstood the hurricane winds as well as any species. Evidence suggests that mixed composition should be preserved. At least 100 young trees per hectare of marketable species should be in the stand 2 years before harvest. This stocking requires maintaining the stand somewhat open before this time. Where mahogany was planted in native forests, it suffered more hurricane damage than the native trees, a factor that should be taken into consideration in the future when the next crop is regenerated.

In Puerto Rico, silvicultural treatment began in 1945 with felling unwanted trees. This treatment proved unnecessarily damaging to the residual trees, however, so the strategy shifted to girdling, followed by use of arboricides, leaving the trees to decompose while still standing. The benefits of gradually reducing the proportion of the least-promising trees have appeared so obvious as a preliminary conditioning treatment that they have not been assessed except in small plots.

Refinement of a young secondary forest at about 300-m elevation in Puerto Rico with a mean stem diameter of 15 cm significantly improved the composition of the remaining stand. The number of trees of 10-cm dbh or more was reduced from 798 to 401 per hectare, the basal area was reduced from 14.9 to 7.2 m^2/ha, and the proportion of the basal area made up by potentially market-able tree species rose from 63 to 84 percent.

Eliminating the less promising trees was seen as only incidentally of benefit to the existing potential crop trees, so the strategy shifted to liberation, leaving unproductive trees that were not competing. The growth response to liberation of trees in key timber species has been impressive.

Natural regeneration

With the possible exception of Guadeloupe, the rate of harvesting timber has never been based on knowing the rate of regeneration needed to assure sustainability. Studies in Dominica report "adequacy" of regeneration, based on an assumed continuation of measured diameter growth (Bell 1976). In Dominica and Puerto Rico, sheer quantity has been used as the measure of sustainability, although significant changes in forest composition clearly are indicated (Wadsworth 1949, Milne 1987, Zamore 1988). Milne (1987), having found 77 overstory trees per hectare of 60+ cm dbh and 105 from 30 to 59 cm dbh, proposed a 90-cm minimum dbh for felling, and a 30-year cutting cycle, obviously counting heavily on *D. excelsa.* In Tobago, after a hurricane, natural regeneration of *Hieronyma caribaea, Byrsonima spicata, Andira inermis,* and *S. amara* appeared in such abundance before the site could be replanted that it later had to be thinned (Dardaine 1991). These studies did not address felling losses or follow up on survival and growth of the residual stand and regeneration thereafter.

Research results

An attempt to replace essentially empirical timber management with practices more scientifically founded led to studies of the growth of the trees in these mountain forests, particularly in Puerto Rico and Guadeloupe. Tree growth was assumed to be more reliably synthesized into stand performance than would be estimating tree growth from the stand as a whole. Published records of tree growth in the natural stands of the region are rare, although unpublished sets of data are thought to exist on several islands. A general problem has been continuity of comparable remeasurements of individual trees, together with interpretation in terms of their management.

Tree-growth measurements in the mountain forests of Puerto Rico, started in 1943, have continued for decades; some of them are in published form (Crow and Weaver 1977). An 18-year record of 273 trees in old, lower montane rain forest from 210- to 600-m elevation gave a mean annual growth of 0.38-cm dbh. The figure is not particularly meaningful in that it includes many species and an array of stem diameters from 10 cm to the large dominants. Maximum growth rates of 117 trees of *D. excelsa* in forest denser than 30 m^2/ha in basal-area range up to 0.81 cm per year and to 1.35 cm for some other species.

Further research, with 24 years of records for 15 tree species in the lower montane forest of Puerto Rico, showed differences of 5 to 1 in stem basal-area increment expressed in percentage of mean basal area of each tree for the period, the latter presumed to measure the forest area apparently being used by each tree's crown and root system (Wadsworth 1987). This index, termed "growth efficiency", was found unrelated to variations in the summed basal area of neighboring trees thought to be competitors. Rather, fast-growing trees were more commonly among relatively dense groups also growing rapidly, apparently as a general response to an especially favorable and extremely local microenvironment. Recognition of fast-growing trees within species from purely their outward appearance or abiotic microenvironment is not yet reliable.

Progress has been made in Puerto Rico in interpreting short-term stem-growth measurements as indicators for longer periods. Relatively constant basal-area increment was found during two successive 20-year periods for many trees in an undisturbed lower montane rain forest. This finding led to a hypothesis that the successful trees, after a period of waiting as suppressed saplings, received an opportunity to leap upward and fill a niche in the canopy. Having accomplished this leap, their subsequent growth in biomass, expressed in terms of stem basal area, remains relatively constant. Plotting backward in time to zero, the 40-year average basal-area increment for each of 248 trees suggested that more than one-third apparently began their current increment rate (presumably stimulated by a canopy opening at that time) within a year of the four hurricanes that affected the forest during the present century, tending to support the hypothesis. This finding apparently confirms a locally unfounded assumption that, in stable forests, a short-term record of the basal-area increment of each tree should be a good indicator of its past and prospective performance over longer periods and possibly even its approximate age.

The slow growth of trees in dense stands and the contrast in growth rates between dominant and suppressed trees (Wadsworth 1947) have suggested that liberating trees potentially more valuable because of their species and form should accelerate their growth. Results from informal studies in Puerto Rico indicate that removing overtopping or close neighbors to preferred crop trees indeed does result in growth acceleration; some of the liberated *D. excelsa* and *Manilkara bidentata* trees grew more than 1 cm in dbh per year. Results, measured in terms of mean annual increment only for small plots, suggest that 5 m^3/ha annually might be possible. Stronger evidence of the potential increment of the mixed mountain forests was not found. These findings tend to support the 80-year rotations anticipated in the natural forests of the mountains of Guadeloupe (Anonymous 1992a).

A future course

Future efforts to make the forests of the islands produce wood deserve serious reflection, in view of growing demand for other forest values, most of which might be jeopardized by timber removal, and the changing market prospects. Contrasting with these considerations is the increasing need to make the forests of recognized value to rural communities otherwise likely to invade them. On each of the islands, these considerations should clarify if, to what degree, where, and how timber might be produced. Compared with the past, the lands available may well be less extensive and even there, the emphasis on timber production may best be shared with other forest interests. One recommendation on behalf of wildlife that may not be difficult to meet in steep mountains is to leave large tracts of unmodified forest mixed with production areas (Evans 1988).

Where the decision may be to proceed with timber production in the native forests of the mountains, a few—not altogether new—axioms would seem to bear emphasis:

- Limit harvesting and productive forest operations to the extent possible to secondary forests, either cutover or volunteer, sparing the primary forests for other values.
- Maintain throughout a permanent forest cover, felling trees only selectively.
- Conserve for the present the minimum-dbh cutting limit to protect immature trees, assuring that the limit is high enough for seed crops from the trees that are left.
- Supervise logging closely to minimize damage, processing at the stump and using animal power or overhead extraction systems wherever appropriate.
- Divert runoff water and revegetate skid trails when their use is terminated.
- Liberate cutover forests promptly after logging is finished, favoring up to 100 selected immature trees per hectare by release from competitors—that is, trees that either overtop or are adjacent—and **taller** than—the selected trees.
- Conserve all trees, regardless of species or size, that are not competing with those of the selected future crop.
- Monitor a repetitive sample of the crop trees and natural regeneration vis-a-vis their microenvironment to improve the basis for future culture.
- Monitor the forest fauna throughout the area in ways that compare trends where silviculture and harvesting are and are not practiced (Wunderle 1994). Mitigate adverse effects as needed.
- Improve utilization of trees harvested, in the tree, in the forest, and during processing. Apply safe wood-preservative treatments.

The cutover forests native to the mountains, despite any past lack of fully regulated utilization, and despite any perception of worthlessness, generally contain more potentially useful trees than is suspected. Past trends foretell that future markets will accept more species than at present. Some tree species of promise capable of growing to 60 cm dbh in the mountains of the Caribbean islands are listed in table 4. To the degree that environmental precautions permit, silvicultural treatment should shift forest composition toward those species best suited for local artisans or furniture makers. For artisans, many additional small trees produce suitable, attractive woods.

The significance of table 4 is that at least 32 large, heretofore known-to-be useful tree species are growing naturally in the mountain forests, most of them on several islands. Emphasis is placed on species with woods suitable for artisans because both the supply and the prospective market appear to favor the developing crafts that can survive on small wood volumes, add much value with labor-intensive work, and meet the growing tourist market. Reportedly, in Monserrat alone, 50 people have worked as artisans (Anonymous 1993).

Table 4—Useful trees native to the mountain forests[a]

Species	Wood: Utility	Wood: Specific gravity	Shade tolerance	Growth rate
Amanoa caribaea Kr. & Urb.	A	0.38	T	S
Andira inermis (W. Wright) DC.	A	0.64	T	S
Beilschmiedia pendula (Sw.) Benth.	A, C	0.54	I	M
Buchenavia capitata (Vahl.) Eichl.	A, F	0.61	I	R
Byrsonima spicata (Cav.) H.B.K.	A, C	0.64	I	S
Carapa guianensis Aubl.	A, F	0.56	T	M
Catalpa longissima (Jacq.) DC.	A, F	0.70	I	M
Cedrela odorata L.	A, F	0.40	I	R
Chimarrhis cymosa Jacq.	A, C	0.75	I	R
Cordia alliodora Cham.	A, F	0.48	I	R
Dacryodes excelsa Vahl.	A, F	0.53	T	M
Dipholis salicifolia (L.) A. DC.	A, C	0.95	I	M
Guarea guidonia (L.) Sleumer	A, F	0.51	T	R
Hibiscus elatus Sw.	A, F	0.62	T	R
Hieronyma caribaea Urb.	A, F	0.65	I	S
Inga laurina (Sw.) Willd.	A, C	0.62	I	S
Licania ternatensis Hook.	C	0.91	T	M
Manilkara bidentata (A. DC.) Chev.	A	0.82	T	M
Micropholis chrysophylloides Pierre	A	0.77	T	M
Ochroma pyramidale (Cav.) Urb.	Insulation	0.22	I	R
Pinus occidentalis Sw.	C	0.68	T	S
Podocarpus coriaceus L.C. Rich.	A, F	0.61	T	S
Pouteria multiflora (A. DC.) Eyma	A, C	0.74	I	S
Protium attenuatum (Rose) Urb.	A, F	0.61	I	M
Prunus occidentalis Sw.	A, F	0.78	T	M
Schefflera morototoni (Aubl.) M., S. & F.	A, toys	0.40	I	R
Simarouba amara Aubl.	A, C	0.32	I	R
Sloanea berteriana Choisy	A	0.95	T	M
Sterculia caribaea R. Br.	C	0.59	T	R
Tabebuia heterophylla (DC.) Britton	A, F	0.58	I	M
Tabebuia serratifolia (Vahl.) Nichols	A, C	0.92	I	R
Talauma dodecapetata (Lam.) Urb.	A, F	0.64	T	M

[a] Utility "C" = construction, framing, and trim; "F" = cabinet work, furniture, and boats; and "A" = easy for artisans to work, or capable of high polish when turned or carved. Specific gravities mostly from Longwood (1962), Chudnoff (1984), and Parant and others (1987). Shade tolerance (T = tolerant; I = intolerant) and relative growth rates (S = slow, M = moderate, and R = rapid) are observational, partly from Marshall (1939).

Timber Production from Plantations

A rationale for plantations

More effort in the islands has been focused on forest plantations than on managing the natural forests. One reason has been the recognized need to reforest degraded and eroding mountainsides cleared for farming and abandoned. Another has been the prospect of introducing woods of the hundred-fold-wider selection from similar tropical environments elsewhere that are more highly valued in the market than those of the native forests. A third has been that, with population growth, land area on the islands is becoming more limiting, calling for the higher productivity per hectare that has been achieved elsewhere with successful plantations. Moreover, production from plantations on the lower slopes of the mountains can at least postpone further intervention and deterioration of native resources farther up the slopes.

Planting trees requires a clear vision of the final objective. Planting, even with native species, has proved neither inexpensive nor necessarily able to produce rapid reforestation or high timber yields. If the energy and financial costs of planting are combined and compared with natural regeneration, plantations are much less rewarding (Odum and others 1997); natural regeneration should be the only option on sites where timber harvesting may prove undesirable because of the likelihood of serious environmental damage.

Several practices have been tested to establish plantations. Most outwardly beneficial appears to be reforesting eroding deforested slopes. Relatively benign environmentally is the enrichment of cutover or volunteer native forests, planting trees of superior potential in gaps. Also tested has been complete underplanting with the intent to replace secondary forest with more productive planted trees within one generation.

Each of these practices has a potential contribution to make, the magnitude of which depends on the details. None of them should reduce protection of soil resources, although some planted tree species might reduce the total runoff of rainwater. Their effects on wildlife also depend on the physical configuration and the tree species planted because large plantations of few species, particularly exotics, may benefit the fauna less than a more diverse, mixed, native-tree component.

Experience to date

Forest plantings have been tried on the mountains of all the islands, nearly all on government lands at public expense; few have been spectacularly successful. Several common causes have been cited for the anomaly of many failures to produce timber on what were formerly forested lands. The following **faulty guidance** has been a common cause in the islands:

- Where soil and water conservation on moist slopes is the principal objective, planted trees may restore protection of severely degraded sites more effectively than mere exclusion of human and animal interference and fire, permitting natural forest regrowth.
- Tree species native to the area are believed capable of tolerating the same site even when it is degraded.
- Native tree species are assumed to tolerate regeneration under conditions of nursery production and planting very different from those of the natural forest.
- Native tree species whose former prevalence was actually a result of competitiveness in natural forests are assumed to be capable of rapid growth in plantations.
- Tree species native within the political boundaries of an island are thought adapted throughout the island.

- Native tree species should have few pests that could forestall pure plantations.
- Exotic species successful elsewhere may be propagated easily and planted anywhere.
- Nursery scheduling need not consider planting season.
- The size of the post-planting weeding task is not a constraint on the rate of planting.
- Selection of tree species for rapid early growth is more important than the marketability of their timber.

The record indicates that Jamaica probably leads the islands in experience in mountain planting, with more than 23,000 ha (Anonymous 1987-1991). Guadeloupe apparently has planted more than 13,000 ha in the mountains (Rousseau 1977), Puerto Rico somewhat more than 5,000 ha, and Martinique 1,200 ha (Anonymous 1992b). Planting in Cuba has been extensive, but actual areas are incompletely documented. Except in Jamaica, few of these plantations have been harvested, so the results are still preliminary.

The chief species used for reforestation has been *Pinus caribaea*, mostly with seed from Belize (Francis 1992). It has proved adapted to mountain sites, including degraded sites, up to 600-m elevation (Soubieux 1983) with 200 cm of rainfall annually (Anonymous 1983). Jamaica's pine, like most of it, has been unthinned because thinning has been considered too costly (Anonymous 1983). Trees 15 cm and up are harvested, an average of 25 cm being expected after 20 years. Since Hurricane Gilbert heavily damaged the pine plantations of Jamaica, the trend there is to plant mahogany and mahoe, considered more resistant (Edwards and others 1993). The mountain pine of eastern Cuba and Hispaniola, *P. occidentalis*, has been planted only sparingly. Dominant trees in natural forest at Mont des Commissaires, Haiti, at 1,600-m elevation, had rings indicating growth to 30 cm dbh in 40 years and to 41 cm in 60 years.

Second to pine apparently is big-leaf mahogany, *Swietenia macrophylla,* from seed obtained in Central America and Venezuela (Bauer and Francis, in press). This species is unequaled in combined ease of propagation, adaptability, machinability, appearance, and resistance to drywood termites (Wolcott 1946). Beginning in 1924 in Martinique, this species has produced impressive pure and mixed plantations at between 300- and 550-m elevation. In Guadeloupe, Martinique, and Puerto Rico, it has been underplanted at wide spacing (7.5 to 10 m between lines) in the native montane forest. It transplants well bare-rooted and makes good early growth, if provided with exposure from above. The species is not windfirm except on the ridges where the root system penetrates exposed boulders. A record tree at 450-m elevation in Puerto Rico attained a dbh of 107 cm in 44 years. The mean, however, is closer to 50 cm. In Martinique, a group of 17 inventoried mahoganies 50 to 60 years old attained 30 to 40 m in total height but only 38 cm in mean stem diameter (Anonymous 1992b). In Guadeloupe as in Puerto Rico, where underplanting survival was poor, the resulting forest is a mixture of planted and naturally regenerated native trees, a condition that should, by the end of the rotation, clarify the future roles of each. In Martinique, a mixture of 75 percent mahogany and 25 percent native species is foreseen.

Mahogany performance has been studied most intensely in Guadeloupe (Soubieux 1983) and in Martinique (Tillier 1995). In Martinique, at elevations between 200 and 600 m, growth data indicate highly variable yields for a rotation of 50 years (Chevalier 1987). In Guadeloupe, results from 37 plots in plantations from 19 to 35 years old gave mean annual increments ranging from 2 to 17 m^3/ha, with the average nearly 8 m^3/ha, well above those of present native forests. The best sites in Guadeloupe are in west-facing coves with soil pH of 5 or more (Soubieux 1983).

The experience of Martinique with mahogany is perhaps the most systematic and worthy of reporting (Chabod and Peters, in press). On Site Class 1, from 300- to 450-m elevation on the windward slopes, mahogany attains a mean total-tree height of 35 m at 50 years. Site Class 2 is between 450 and 600 m, mostly on the leeward slopes, with a mean total-tree height of 29 m at 50 years. Many plantations were established on slopes in excess of 50 percent, where it has proved difficult to harvest the timber. Pure plantations with spacing as close as 2 x 2 m were successful with taungya but discontinued in 1971, when the shift was to underplanting at a spacing of 2 x 4 m. Bare-root stock 1.8 m tall is planted; cleanings are required four times the first year, three times the second, twice the third, and once the fourth year. Cleaning must be thorough because of the hazard of poisonous snakes.

In Martinique, 100 percent of the planted trees have been attacked by the shoot borer, requiring stem pruning (Chabod and Peters, in press). The attacks are less in the shade, leading to the current practice of underplanting and striving for 30 percent of the stand to be other species. Root-rot reportedly affects about 8 percent of the trees. Current thinning practice is to reduce the number of trees per hectare at 15 years from 1,100 to 900, to 500 at age 21, to 250 at age 28, and to 150 at age 35.

Mahogany yield predictions from plots to 44 years old in Martinique show its potential (Chabod and Peters, in press). For Site 1, yields on a 50-year rotation include trees to 65 cm in dbh, stand basal area of 53-57 m^2/ha, and a mean annual increment of 20 m^3/ha. On Site 2, at 50 years, tree diameters range to 60 cm, the basal area 47-51 m^2/ha, and the mean annual increment about 14 m^3/ha. These yields are not cost effective, and several steps are proposed to reduce costs. The use of underplanting reduces the shoot-borer problem. Chemical treatment for cleaning is proposed, and heavier thinnings are proposed to accelerate diameter growth.

The tree species apparently third in extent planted in the islands is *Hibiscus elatus,* native to Jamaica (Weaver and Francis, n.d.). The tree is well adapted to the mountains and produces a cabinet wood that should compete in quality with imports. Plot means for trees in Puerto Rico range up to 45 cm in dbh in 27 years (Weaver and Francis n.d.). The species has a narrow crown for a broad-leaf tropical species, about 12 times as broad as the dbh, so it withstands high stand density. Heavy thinning in Puerto Rico produced undesirable epicormic branching.

Few other tree species have been planted often enough to produce conclusive results. In Puerto Rico, some 225,000 wildings of the native *Tabebuia heterophylla* were planted to reforest abandoned pastures above 300-m elevation with great success, albeit moderate dbh growth averaging 0.38 cm/yr (Weaver 1990a). It has been a popular wood for doors and furniture on several of the islands. *Cedrela odorata*, planted on about 800 ha in Puerto Rico, proved unadapted, as it has where planted almost everywhere else in the region (Beard 1941). The quality of the wood and the growth rate of successful trees (to 50 cm dbh at 20 years, Cintrón 1990) is such that some of the islands continue to test this species. Similarly, *Cordia alliodora* has been planted sparingly and, on some sites, has made impressive growth to about 30 cm dbh, when it slows (Liegel and Stead 1990). *Podocarpus coriaceus,* planted on about 600 ha in Guadeloupe, is surviving, but its growth suggests a rotation of 100 years (Montaignal n.d.). Many species of *Eucalyptus* planted in the mountains of Puerto Rico have done best above 500-m elevation. Some species are adaptable and rapid growing but most of them are difficult to use. Most impressive is *E. deglupta* (Francis 1988).

In Puerto Rico, a few other native tree species have been tested with indifferent results. *Calophyllum calaba,* a coastal species direct seeded, has proved capable of reforesting the poorest mountain sites, but its growth is slow and form is poor, so it is little more than a rugged nurse crop under these conditions. Diameter growth-rate maxima under these conditions in Trinidad average no more than 0.14 cm/yr (Weaver 1990b). *Pouteria multiflora* (Parrotta and Francis 1993) and *Byrsonima spicata* (Francis 1990) were both planted with similar results. The mean dbh of *Pouteria* at age 55 reached 29 cm, and for *Byrsonima* at age 45, the largest tree was 29 cm in dbh. *Manilkara bidentata,* once it was discovered that the seeds germinate better in litter than in soil, proved to be capable of more rapid growth than would be suggested by the high density of its wood. A 17-year-old plantation in the Luquillo Mountains of Puerto Rico averaged 0.51 cm per year in dbh growth (Weaver 1990c). In the modern world, such a dense wood is useful for artisans only. *Prunus occidentalis* appears to deserve more attention (Alemañy 1997). Native to many of the islands and in Puerto Rico to 800-m elevation, the tree has dense, red, extremely attractive wood. The tree is well formed, growing to 50 cm dbh in 40 years at an elevation of 500 m in Puerto Rico.

A Case Study: Plan Sierra

Beginning in 1979, the Dominican Republic undertook a mountain forest project of interest to the entire region. Two characteristics of the project were probably unique to this region: The first integrated forest management into a comprehensive program for rural development, and the second promoted the needed forestry through private individuals.

The information presented here comes from reports from Blas Santos, Executive Director in 1980 (Santos 1980), Monseñor Roque Adames (Adames 1990), and Swedforest (Anonymous 1991c), and interviews with José Elias Rodríguez, current Executive Director, and Constanza Casanovas, former staff member.

The project began with the assignment by the government to the project of some 175,000 ha of land in the central mountains between 200- and 1,500-m elevation. The climate includes five of Holdridge's (1967) life zones: Subtropical dry, moist, and wet, and lower montane moist and wet forest. Slopes commonly exceed 50 percent, and nearly all the soils are unsuited for cultivation. Erosion rates as high as 4 metric tons per hectare in two rainy weeks have been recorded.

At the outset, about 18 percent of the land was forested, mostly with *Pinus occidentalis.* The rural population, 40 percent of them below the poverty level, were engaged in shifting subsistence agriculture, making restoration of the land with permanent crops inconsistent with the local urgency for food production.

The project, although administratively within the Secretaria de Estado de Agricultura of the National Government and supported primarily with public funding, was placed in the hands of a semi-autonomous Board of Directors, including prominent citizens of the region. Apparently under strong leadership, a regional organization was created to serve the many small communities in the area. It undertook a broad program of betterment of human conditions, improving communications, education, and medical services. Using subsidies and technical assistance, agricultural improvements, such as better seed; and shifts to less-erosive crops, such as bananas and coffee, have been encouraged.

Training in conservation and forestry was introduced, and reforestation was undertaken on lands offered by the residents. Nurseries were created, most of them local, near lands to be planted. Some 5,000 ha of plantations are reported. Using Swedish technical assistance, a demonstration forest of about 3,000 ha was inventoried and placed under management plans calling for yield regulation, reforestation, and silvicultural improvement. A sawmill, the only legal one in the country—thus with a captive market—was installed. Companion to it are debarking and preservative-treating facilities, charcoal kilns, a briquet plant, and another plant for extracting turpentine. Field crews have been trained, and some 600 persons are employed. The forest utilization facility, operating under sustainable-yield constraints, is currently the largest source of income funding the program.

Because the reforestation goals depend largely on private initiative, they have not been achieved, although as many as 100 landholders reportedly are interested. Calculations by the project indicate that managing the existing pine forest could yield 14 percent above inflation, and new plantations should yield 6 percent. Anticipated mean annual increment for *P. occidentalis* is 7.5 m^3/ha and for *P. caribaea,* 10 m^3/ha.

What looks like a remarkably successful project, both technically and socially, is not yet over all the obstacles. From the beginning, assuring stable funding has been difficult because of the disparity between the long-term payoff and the nearer goals of political appointees and the many social benefits that are unquantifiable, however great they may appear.

Paradoxically, what outwardly may seem to be an unusual success is apparently at the root of growing problems. The project is reported to look like an independent empire, a privileged region unanswerable politically. The very fact that the program is largely internally funded from the project's own forest industry strengthens this perception. Rumors of internal scandals have circulated, and local political support is said to have been withdrawn. Some elements of the press have become hostile; and a political takeover has been threatened.

Adames (1990), after some ten years as Director, concluded that the project has perhaps served its function, that of developing demonstrations, techniques, information bases, and trained personnel. He felt that it may be time for national policies to take over more directly, providing clear and stable legislation assuring the needed infrastructure to develop forestry, an agency administratively and technically capable of directing an effective program. He further suggested that although incentives should be offered to landowners to reforest, they should be either required to do so or turn their land over to the government for this purpose. He foresaw a policy of liquidity in forest lands, facilitating both purchases and sales.

Priorities for Research and Application

The status of forest management in the mountains of the islands reflects fundamentally a lack of knowledge. Inadequate knowledge of the full benefits of management has restrained governments and private interests from assigning priority to investing in them. For the same reason, what has been attempted has mostly been based on decisions made without full knowledge of the consequences. At worst, decisions based on inadequate knowledge have led to failures that further constrain investments in management. At best, it produces knowledge that is superficial, merely the information that something "works", but usually not why. Frustration results when what worked on one site, year, or tree species fails under apparently similar conditions in subsequent attempts, all at a cost in economic terms and in credibility of forestry as an investment. Whenever a new effort is undertaken, this kind of knowledge does not eliminate much critical guesswork.

An explanation for the causes of this situation is not obscure: Forest management developed earlier under other conditions and distant from this region. Managers from the islands have mostly received their forestry training under these distant conditions, so much outside knowledge has been applied to local circumstances. Common examples are the assumptions that removing trees thought overmature inevitably improves the productivity of the residual forest, the belief that tree species formerly native to a site must be suited for its reforestation, and that exotic tree species should be selected over natives on the basis of their performance somewhere else. These "trial and error" judgments have a poor record of success in the islands. Secondary forests are abandoned because of slow response to silviculture, and most plantations grow poorly, probably for a variety of unknown reasons.

Even where production practices have been thought successful, more is now apparently involved than mere rate of growth of potentially useful trees. Sustained forest production also requires not only regeneration of assured quality but also conserving nutrients and the wildlife that are integral to the welfare of the forest. These factors depend on some degree of forest biodiversity, the preservation of which may reduce "productivity" in the economic sense. The long-term nature of returns from forest production and the intricacies and subtle character of what is required easily explain why forest research has been neglected in the islands of the Caribbean. Even in Jamaica, one of the larger and wealthier islands, forest research reportedly is undertaken only if funded from outside (Anonymous 1983).

Research supported from outside the islands has made a contribution to the foundation for local forest management. Examples are publications on the flora (Anonymous 1919-1957, Howard 1974-1981, Liogier 1985-1997), the natural history (Bond 1961, Woods and Ottenwalder 1992), the soils (Hardy 1940), and the forests (Beard 1949). The outcome of these studies has been supportive of forest protection more than forest manipulation for its productive benefits for human society. Major studies contributing to forest culture have been reported by Marshall (1939) on silviculture, of Labbe (1982) on natural regeneration, of Soubieux (1983) on mahogany production, and of Longwood (1962) and Parant and others (1987) on wood properties.

A gap exists between the fundamental research to uncover and explain forest phenomena and pragmatic observation of the tree and forest performance responses to management policies and practices. The first of these research areas must continue to be funded largely from outside sources. The second, a relatively inexpensive but vital link to early progress, needs to be developed locally; it requires trained, career people close to the scene over time and systematic testing, interpreting, and applying the results.

A creditable description of research needs in the English-speaking islands is that of Briscoe (1992). Several of his recommendations directly address needs of forest management in the mountains that can be met at least partially by systematically observing and applying the findings of existing local personnel. These findings are described briefly here:

- Developing a continuous forest inventory. Initially, with local resident participation, define the objectives clearly. Limit the inventory to highest priority forests first. Include all resources, and involve multidisciplinary participation. Assure potential for comparative, repetitive sampling to show any trends. Interpret in terms effective in producing public support for better forest protection and management.
- Strengthen preservation of representative primary-forest ecosystems, habitats, and species. Document and publicize their national importance, based on reliable assessments. Assure representation of diverse sites rather than excessive representation of those still best forested. Determine and accept limits of human uses compatible with preserving these forests.
- Determine existing social attitudes germane to managing mountain forests, with special emphasis on the people who most depend on them. Use the information to motivate public support for good management of the forests.
- Prepare for governmental approval and implement long-term, comprehensive plans for managing timber-production forests. Include high visibility to the public of all forest treatments and provisions for comparative testing of the effectiveness of different silvicultural practices.
- Develop systematic, inexpensive practices for testing tree propagation and establishment with different species and provenances on diverse sites and the culture of established timber plantations. Develop and apply comparative criteria for rating different practices.
- Explore and promote opportunities for new local uses of existing woods, preservative treatment, and energy generation, including fuelwood and charcoal efficiency.

In one seasoned local opinion, the region collectively has enough expertise for most of the activities needed to protect and manage the forests (Lackhan 1992). Nevertheless, implementing each of these technical steps would, for most islands, require training people to carry them out. With the blessing of local governments, each activity could begin with a regional workshop led by appropriate specialists to develop consensus processes of advantage to all. Outside forestry assistance thereafter should be better focused than in the past; the positive results should be well worth the investment.

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Two elevations—above 800 m and above 300 m—define the montane forests of the Caribbean islands. Of the 36 islands considered, 27 have mountains above 300 m and 14, above 800 m. Of the 233,000 km^2 of the islands, at least 118,000 km^2 are above 300 m, and 60,000 km^2 are above 800 m. At least 20,000 km^2 above 300 m and 10,000 km^2 above 800 m are covered by forest. Significant areas of montane forests have been legally reserved, with at least protective management on the larger islands. An ambitious, community-oriented, multiple-forest land-use program has been under trial for many years in the Dominican Republic. Silvicultural practice for timber production is limited largely to plantations; at best, yields are promising. Further research and strengthening of public policies and forestry programs are needed throughout the region.

Keywords: Caribbean, forests, mountains.

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