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Upland Forests of the American/Pacific Islands: Research Opportunities in Micronesia and American Samoa

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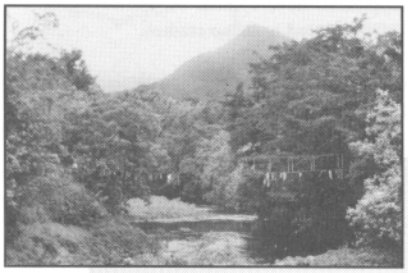
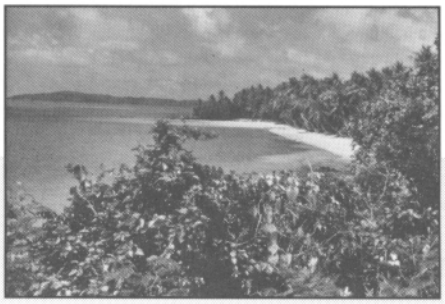


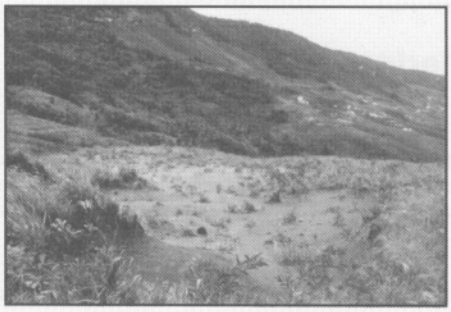
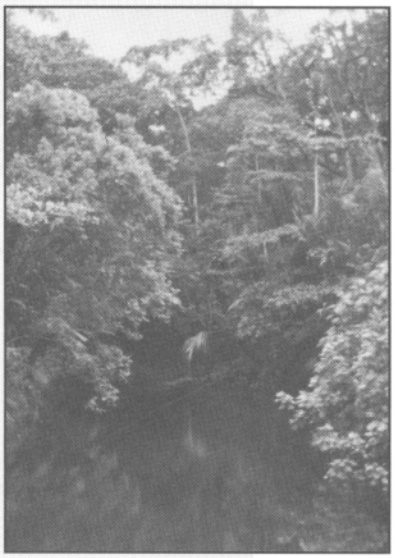
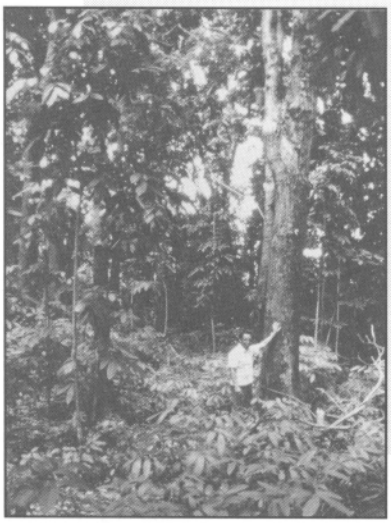


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Upland forests of Micronesia and American Samoa can provide many social, ecological, and esthetic benefits for island inhabitants. Substantial upland areas (the majority of acreage on some islands) are now occupied by secondary and grassland/savanna vegetation; such areas represent opportunities for restoration, with both native forest cover and plantations of introduced species. This review briefly describes characteristics of the islands and the nature of existing and potential upland forests, including the most common upland tree species. Principal information needs and research opportunities are discussed for 10 subjects: watershed rehabilitation, forest restoration in secondary vegetation areas, basic ecology, soils and nutrient relationships, damaging agents, forest inventory and productivity assessment, silvicultural systems, valuation of forest products and services, threatened and endangered species, and description and protection of native forest habitats. Finally, suggestions are offered on a strategy for meeting information needs; these include philosophy of approach, development of an infrastructure for cooperative research, and some ideas on establishment of integrated baseline studies.

Retrieval Terms: forest research planning, high-island forests, Pacific Islands silviculture, tropical islands ecology, Micronesia, Caroline Islands, Marian Islands, Guam, Palau, American Samoa

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Cover: The variety of forest and secondary vegetation cover types occurring on islands of Micronesia.

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In Brief...

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Retrieval Terms: forest research planning, high-island forests, Pacific Islands silviculture, tropical islands ecology, Micronesia, Caroline Islands, Marian Islands, Guam, Palau, American Samoa

Upland forests of Micronesia and American Samoa can provide many social, ecological, spiritual, and esthetic benefits for island inhabitants. Unfortunately, most of the original forest on many islands has been removed or degraded as a result of subsistence agriculture, clearing for commercial agriculture, and past utilization of timber resources. Much of the land is now occupied by secondary and grassland/savanna vegetation; it could be restored to forest cover comprised of both native and introduced species. This review briefly describes characteristics of the islands and the nature of existing and potential upland forests, including the most common upland tree species.

Principal information needs and research opportunities are discussed for 10 subjects. *Watershed rehabilitation* and *forest restoration* are needed, particularly on Guam, Yap, parts of Palau, and in the Northern Mariana Islands. Fire must be controlled, and stand establishment methods must be developed. Research on *basic ecology, soils and nutrient relationships,* control of *damaging agents,* and *silvicultural systems* will contribute to the success of restoration programs. Data on *forest inventory and productivity assessment* are necessary for resource planning and sustained yield management. Lack of information and appreciation for the *value of forest products and services is* a serious obstacle to wise use and management; thus, broad-based evaluations, specific to Pacific Island environments and extending beyond mere financial analyses, are needed. Many of the flora and fauna in upland forests of Micronesia and American Samoa are endemic to individual islands or small groups of islands; some are threatened and more may be become so as development proceeds. Information is needed on habitat requirements and factors limiting distribution and size of populations of *threatened and endangered species.* Although there are sizable areas of undisturbed upland forest habitat on some islands, little remains on other islands. Thus, *description and protection* of a well-designed network of *natural forest habitats* are needed throughout the Pacific Islands.

Suggestions are offered on a strategy for meeting information needs. This strategy includes a basic philosophy of approach to research in the Pacific Islands, development of an infrastructure for cooperative research, and some ideas on retrospective analyses to provide near-term information and establishment of integrative baseline studies that can also serve as centers for subsequent activities and technology transfer.

Introduction

Protection and management of tropical forest resources have become political and scientific issues of global concern. Deforestation and other resource degradation have captured headlines for a decade or more. The United States Government is committed to a program of research, technical assistance, and education to protect and sustain tropical forest resources throughout the world (Public Law 101-513, Title VI---the "International Forestry Cooperation Act of 1990"). A portion of this program is aimed specifically at several islands or island groups in the south and western Pacific. These islands include American Samoa (Polynesia) and Guam (both U.S. Territories) and some 2000 Micronesian islands lying in three major archipelagoes: the Mariana, Caroline, and Marshall Islands. Formerly components of the U.S. Trust Territory of the Pacific Islands, the Micronesian islands (excluding Guam) are now aligned in three developing nations and a commonwealth, with varying relationships to the United States: the U.S. Commonwealth of the Northern Mariana Islands (including Saipan, Rota, and Tinian), the Republic of Palau (Belau), the Federated States of Micronesia (Yap, Chuuk [Truk], Pohnpei, and Kosrae), and the Republic of the Marshall Islands.

The Pacific Islands are characterized by rapidly increaseing populations, a limited resource base that continues to be exploited, and inadequate knowledge of the renewability of that base. Although the islands and their native populations may once have been models of sustainability and self-sufficiency, economic assistance from the United States continues to help meet basic food, fuel, and fiber needs. Much of the original forest has been removed or degraded as a result of subsistence agriculture, clearing for commercial agriculture during periods of German (ca. 1885 to 1914) and Japanese (1914 to 1945) occupation, and past utilization of the timber resources. The accelerating development of tourist facilities by foreign investors poses an additional threat to the integrity of some island ecosystems and their capability to sustain basic needs for water, food, fuel, and shelter. Research findings, technology transfer, and conservation education programs emphasizing resource values within the forest ecosystems of the islands can aid in the development of economic self-sufficiency in these emerging nations.

This paper describes the upland forests of Micronesia and American Samoa and examines information needs and research opportunities in major forest ecosystems of these Pacific Islands. An earlier report describes the mangrove forests of the Pacific Islands (Lugo 1991), and a third report, on agroforests, is planned.

Scope and Methods

This review of resource information needs and research opportunities will focus primarily on the upland forest type, but also includes the plantation forest and other vegetation types. Although the composition of such forests is quite diverse and may vary substantially throughout the Pacific Islands, upland forests may be defined as forests where palms do not predominate and where the water table is too low to support mangrove or swamp forest species (MacLean and others 1988a). The term "upland" has been used consistently to designate such forests throughout Micronesia in soil surveys, vegetation surveys, and timber resource reports (e.g., MacLean and others 1988b; Smith 1983a, b; Whitesell and others 1986). However, some publications dealing with tropical and insular forest resource management have used other terms such as "lowland forest" and "lowland rain forest" that encompass the forest habitats discussed in this paper (U.S. Congress, Office of Technology Assessment 1984, 1987). In addition to areas designated as upland forest, this review will also consider research needs of plantation forests and areas now designated as secondary vegetation and grassland/savanna. Both of the latter areas are believed to have originally supported upland forests, but clearing or repeated fires, or both, have led to the present vegetative cover. Secondary vegetation and grassland/savanna represent potential upland forests, and restoration of tree cover in such areas is considered a high priority on some of these islands and elsewhere in the tropics.

Information for this report was derived by several methods, including ongoing field studies. We spent 2 weeks observing forest conditions in Micronesia and discussing resource information needs with local forestry leaders *(appendix A)*. In addition, we reviewed publications and office reports concerning upland forests and resource management in Micronesia, American Samoa, and similar island areas in the tropical Pacific. Finally, we sought review of our draft report and comments from additional leaders in forest management and forest resource science.

This report is organized in three sections. First, we provide a description of the major islands and the nature of existing and potential upland forest areas. Next, we discuss the principal information needs and research opportunities by general topics. Many of the topics, however, are interrelated, and integrated research studies will commonly address needs in more than one topic. Finally, we will suggest approaches to meeting the resource information needs on the islands. Our suggestions will involve philosophy of approach, development of a solid infrastructure for cooperative research, and provide some specific ideas on establishment of integrated baseline studies.

The Islands and Their Upland Forests

The islands considered in this report are scattered throughout the western Pacific. Most of the forested islands of Micronesia lie between 5 and 20° N latitude *(table 1)* and between 130 and 165° E longitude. The five islands of American Samoa lie between 11°03' to 14°32' S latitude and between 168°10' to 171°07' W longitude. Although spread over an area larger than the contiguous United States, total land area is less than that of Rhode Island. Population densities are fairly high (ca. 0.7 to 2.0 persons per dryland acre) in the Mariana Islands, American Samoa, Chuuk, and the Marshall Islands, but substantially lower elsewhere. Population growth rates, however, are quite high on all islands. Annual rainfall is abundant, but uneven distribution throughout the year creates serious problems on many of the islands. There is little fluctuation in temperature, with annual temperature averaging nearly 80° F. Most of the islands discussed in this report are "high islands" of volcanic origin, with portions of some (e.g., Palau and Guam) being capped with limestone. Elevation ranges from sea level to peaks exceeding 2500 feet on Pohnpei, and on Ta'u Island, in American Samoa *(table 1)*. Soils differ considerably in depth, fertility, acidity, and other important characteristics.

Areas of upland forests and of potential forests (secondary vegetation and grassland/savanna areas) are given in *table 2*. Timberlands include all forests capable of producing at least 20 ft^3 per acre per year; other upland forests include land that is either less productive or is too steep for timber management (slopes greater than 100 percent). More than 90 percent of the existing timberland occurs in the Northern Marian Islands and on Palau and Pohnpei; current timber volumes are highest in Pohnpei and Palau. Many of the areas classified as secondary vegetation and grassland/savanna represent opportunities for watershed rehabilitation, forest restoration, and plantation forestry. Much of the land on Guam falls into these two categories; there are also substantial acreages of potential forest land in Palau, Yap, Pohnpei, and on some islands in the Northern Mariana Islands. There are no upland forests or potential upland forests in the Marshall Islands. Major species occurring and/or recommended for management in the existing and potential forests are described in *table 3*. Principal species in upland forests differ by island, but members of the genera *Callophylum, Campnosperma, Elaeocarpus, Horsfieldia,* and *Terminalia* are prominent. Major components of existing secondary vegetation include *Hibiscus, Leucaena,* and *Pandanus.* Introduced genera appearing to have the greatest promise in rehabilitation and restoration efforts include *Acacia, Albizia, Pterocarpus,* and *Swietenia*.

Information Needs and Research Opportunities

Rehabilitation and Management of Island Watersheds

Watershed rehabilitation and the research required to support it have been recognized as a major need in nearly every resource appraisal for the Pacific Islands (Owen 1979; U.S. Congress, Office of Technology Assessment 1984, 1987). The problem is greatest on Guam, Yap, and parts of Palau and in the Northern Marian Islands where substantial areas are not forested. It is believed that such areas were originally covered with trees, but subsistence gardening by large human populations

Table 1-*Characteristics of major islands and island groups*[1]

Island or Island Group	Latitude	Dryland	1980 population	Mean annual rainfall	Approximate number of islands
		acres		--- *inches* --	
American Samoa	14°S	49,200	35,300	100-200	7
Guam	13°N	135,000	119,800	80 - 95	1
N. Marian Islands	14-20°30'N	76,000	18,600	75-120	21
Palau	7.5°N	108,300	13,000	147	350
Federated States of Micronesia					
Yap	6-12°N	27,875	8,200	122	149
Chuuk	5-7°N	20,950	37,500	139	290
Pohnpei	7°N	90,000	22,300	190	165
Kosrae	5.5°N	26,270	5,500	227	5
Marshall Islands	5-12°N	17,945	34,900	135	1,225

[1]Adapted from Table 22 (United States Congress, Office of Technology Assessment 1984) and Table 3-1 (United States Congress, Office of Technology Assessment 1987

Table 2-*Area and timber volume of upland forests In Micronesia and American Samoa*[1]

Island or island group	Timberland	Other upland forest	Volume of timber on timberland	Potential upland forest: Secondary vegetation	Potential upland forest: Grassland/ savanna
	acres		*1000 ft³*	*acres*	
American Samoa	16,600[2]	8,200	8,300	608	403
Guam	n.a.[3] (a few scattered patches)	n.a.	n.a.	70,000	50,000
N. Mariana Islands[4]	25,000	n.a.	n.a.	25,000	9,000
Palau[5]	62,420	2,995	88,638	2,491	16,618
Federated States of Micronesia					
Yap	5,797	516	1,589	1,366	5,374
Chuuk (Truk)[6]	0	0	0	622	429
Pohnpei	25,120	5,874	70,847	4,554	3,656
Kosrae[7]	4,315	8,225	5,754	3,143	42

[1]Adapted from Cole and others 1988; MacLean and others 1988a, 1988b.
[2]Estimated to include upland, palm, and coastal forest areas.
[3]n.a. = Statistics not available.
[4]Estimated from vegetation survey (Falanruw and others 1989).
[5]Figures are for Babelthuap only, but this represents more than 95 percent of the existing and potential upland forest area in Palau (excludes the Rock Islands).
[6]Estimated from vegetation survey of Moen, Dublon, Feban, and Eten (Falanruw and others 1987).
[7]Estimated from vegetation survey (MacLean and others 1988b; Whitesell and others 1986).

Table 3-*Useful forest tree species in Micronesia and American Samoa*

Species:	***Acacia auriculiformus* (Family: *Leguminosae*)**
Common Names:	Auri (Guam)
Land Class:	Plantation forests on grasslands and savannas
Distribution:	Native to New Guinea, N. Queensland, and the Torres Straits
Size:	Small to medium
Height:	Can grow to more than 90 feet tall
Diameter:	To 2 feet
Growth Rate:	Rapid, even on poor, highly acid soils
Wood Characteristics:	Hard, light brown color, often with poor stem form. Specific gravity ranges from 0.60 to 0.75
Uses:	For fuel wood and erosion control; many provenances exhibit poor form, unsuitable for lumber, useful for building soil fertility and tilth
Remarks:	A nitrogen-fixing species
Species:	***Acacia mangium* (Family: *Leguminosae*)**
Common Names:	Mangium
Land Class:	Plantation forests on grasslands and savannas
Distribution:	Native to Queensland, Australia
Size:	Small to medium
Height:	Can grow to more than 70 ft. by age 10 *years*
Diameter:	Grows over 1 inch per year
Growth Rate:	Rapid
Wood Characteristics:	Hard, light brown color
Uses:	Grows well on infertile, eroded sites; a good fuelwood
Remarks:	Some seed sources prone to wind damage; considerable variation in stem form; a nitrogen-fixing species useful for restoration of degraded watersheds

continues

Table 3-*Useful forest tree species in Micronesia and American Samoa, continued*

Species:	***Albizia falcateria* (Family: *Leguminosae*)**
Common Names:	Albizzia
Land Class:	Plantation forest on grasslands and savanna
Distribution:	An introduced species, native to the Moluccas and New Guinea
Size:	Large with clean, straight bole
Height:	Dominant trees attain 75 to 135 feet in height
Diameter:	2 to 3 inches per year
Growth Rate:	Very fast. Capable of vigorous growth on infertile, well-drained soils. Fixes nitrogen
Wood Characteristics:	Soft, light color; specific gravity 0.30 to 0.40
Uses:	Veneer, reforestation of nutrient-depleted soils, furniture, fiber products
Species:	***Albizia lebbeck* (Family: *Leguminosae*)**
Common Names:	Siris-tree, mamis, kalaskas (Marianas), gumorningabchey (Yap)
Land Class:	Plantation forest
Distribution:	A tropical species from Africa to Australia planted from sea level to 4,500 feet in both dry and wet areas
Size:	Large
Growth Rate:	Very rapid
Wood Characteristics:	Heavy (specific gravity 0.55 to 0.90)
Uses:	Promising for fuel and furniture, reforestation of degraded sites
Remarks:	A nitrogen-fixing species
Species:	***Calophyllum inophyllum* (Family: *Guttiferae*)**
Common Names:	Biotu (Guam), fregits (Chuuk), hetau (Pohnpei), eet (Kosrae), luej (Marshalls), aptakas (Palau), daog (Marianas), fetau (American Samoa)
Land Class:	Coastal forests and upland forests
Distribution:	One or more species found on nearly all islands in Micronesia, American Samoa; and on many other austral Pacific islands, and throughout Southeast Asia
Size:	Fairly large, a component of the overstory
Height:	To 60 feet tall; some species in this genus attain heights of 100 to 150 ft
Diameter:	May attain diameters of 2 to 4 ft
Growth Rate:	Slow
Wood Characteristics:	Heartwood deep red to pink brown. Specific gravity varies from 0.40 to 0.65, interlocking grain
Uses:	Flooring, light construction, boat building, craftwood, beautification plantings
Species:	***Campnosperma brevipetiolota* (Family: *Anacardiaceae*)**
Common Names:	Thong (Pohnpei), eet, elak (Kosrae), ramala (Yap), charm (Palau), dohng (Pohnpei)
Land Class:	Upland forest
Distribution:	A native species in the Caroline islands
Size:	Large, a component of the overstory
Uses:	Flooring, canoes, boxes, and handicraft
Remarks:	A major component of existing timber volume on Palau, Yap, and Pohnpei
Species:	***Elaeocarpus* spp. (Family: *Elaeocarpaceae*)**
Common Names:	Nanek (Kosrai), sadak (Pohnpei), maratte (Pohnpei), degemerir (Palau)
Land Class:	Upland forest
Distribution:	Native to Micronesia and American Samoa. Numerous species found throughout the tropical Pacific. A major species on Palau, Pohnpei, Kosrae, Guam, and Samoa
Size:	Medium to large, great differences among species
Wood Characteristics:	The wood is light and not very durable, medium soft to hard
Uses:	Some species recommended as ornaments, suitable for inside work

continues

Table 3-*Useful forest tree species in Micronesia and American Samoa, continued*

Species:	***Hibiscus tiliaceus* (Family: *Malvaceae*)**
Common Names:	Hau (Pohnpei), aramal (Palau), Law (Marshalls), Lo (Kosrae), kilife (Truk), fau (American Samoa)
Land Class:	Secondary vegetation
Distribution:	Probably of Old World origin, reported to be native to Cuba and Jamaica
Forest Component:	Frequently found in secondary, scrub vegetation
Size:	Small, with multiple stems
Growth Rate:	Rapid
Wood Characteristics:	A light, tough wood; specific gravity 0.62
Uses:	Cabinets, furniture, trim, construction. Bark of young trees used for cordage
Remarks:	A multipurpose species throughout the tropical Pacific Islands (considered a weed in Hawaii)
Species:	***Horsfieldia* spp. (Family: *Myristicaceae*)**
Common Names:	Nunu (Kosrae), ersachel (Palau)
Land Class:	Upland forest and swamp forests
Distribution:	Several native species in Micronesia; one on Kosrae and three on Palau. A major component of forests on Kosrae and Palau
Size:	Generally large
Wood Characteristics:	Light reddish brown heartwood, not difficult to work with
Uses:	Temporary construction, furniture, boxes
Species:	***Leucaena leucocephala* (Family: *Leguminosae*)**
Common Names:	tangan-tangan (Guam)
Land Class:	Secondary vegetation
Distribution:	A native to tropical America, now well distributed throughout the Pacific Islands
Size:	Shrub or small tree, up to 13 to 16 feet tall, sometimes taller
Growth Rate:	Very rapid
Wood Characteristics:	Fairly heavy
Uses:	Good wood for making charcoal
Remarks:	Often occurs in pure stands, uncommon on acid, volcanic soils
Species:	***Pandanus* spp. (Family: *Pandanaceae*)**
Common Names:	fais (Palau), Ka fo (Marianas), bob (Marshalls), men oa (Kosrae), fahss (Pohnpei), faar (Truk), choi (Yap)
Land Class:	Secondary vegetation, grasslands, and savanna areas
Distribution:	Common tree throughout the Pacific
Size:	Small
Uses:	Leaves used for thatch, baskets, mats, and hats; eaten during crop failures in Marshall Islands
Species:	***Pterocarpus indicus* (Family: *Leguminosae*)**
Common Names:	Narra las (Palau), angsana (Marianas), arao (Yap)
Distribution:	Native to Southeast Asia and the Philippines
Size:	Large
Height:	Grows to more than 80 feet tall
Diameter:	Attains 3 ft
Growth Rate:	Moderate
Wood Characteristics:	Durable, medium soft
Uses:	A very fine furniture wood
Remarks:	A nitrogen-fixing species useful for reforestation purposes; cuttings root easily

continues

Table 3-*Useful forest tree species in Micronesia and American Samoa, continued*

Species:	***Rhus taitensis* (Family: *Anacardiaceae*)**
Common Names:	Tavai (Samoa), galad (Yap), chaues (Palau), lamahu (Marianas)
Land Class:	Upland forests
Distribution:	A native species to American Samoa, Palau, Yap, and Guam; common at low and medium elevations
Size:	Medium
Species:	***Swietenia macrophylla* (Family: *Meliaceae*)**
Common Names:	Bigleaf Mahogany
Land Class:	Plantation forest
Distribution:	An introduced species from Central and South America
Size:	Large
Height:	May surpass 80 feet
Diameter:	Older trees exceed 2 feet in planted stands
Growth Rate:	Rapid
Wood Characteristics:	An excellent timber to work with, durable, and finishes well
Uses:	Boat planking, veneers and for panelling, craftwood
Remarks:	Well adapted to growing conditions in the tropical Pacific
Species:	***Terminalia samoensis* (Family: *Combretaceae*)**
Common Names:	Kin (Pohnpei and Truk), kil (Yap), ekkon (Marshall islands), chesemiich (Palau), talisai ganu (Marianas), Talie (American Samoa)
Land Class:	Both upland forests and coastal forests
Distribution:	A native species present throughout Micronesia and American Samoa
Size:	Large, usually in the overstory
Height:	± 75 feet
Diameter:	Can exceed 3 feet
Uses:	Furniture, decorative veneer

during earlier periods before contact with outsiders (e.g., Yap, see Falanruw 1991) and clearing for commercial agricultural production of primarily copra by the Germans and of sugar cane and pineapple by the Japanese resulted in extensive areas of grassland and savanna vegetation. Such vegetation types are subjected to repeated fires and erosion, with associated losses of soil fertility, deterioration in the storage and quality of water, siltation of coastal waters and reefs, and degradation of marine fisheries and other biological resources.

There are two prerequisites for successful rehabilitation of these areas. One involves resources for and commitments to public education about adverse effects of uncontrolled burning, enforcement of arson laws, and suppression of fires (Noquez 1988). Some research on sociological aspects of indiscriminate burning and on fire-danger rating systems is appropriate, but provision of most of the above needs lies primarily within the domain of local forestry and land management organizations and the USDA Forest Service Pacific Southwest Region's State and Private Forestry Branch. The second prerequisite to successful rehabilitation of these watersheds involves research to develop methods for restoring forest cover. Moreover, surveys of the general health of island watersheds to identify serious problem areas, including evaluation of the sources and routing of sediments (and their effects on the mangrove resource), would also be complementary. The surveys would help focus both research and operational efforts on restoration priorities. Work on watershed restoration should be planned and done in collaboration with the USDA Soil Conservation Service as well as local forestry and land-management organizations.

Considerations in the development of restoration methods and selection of species include enhancement of soil productivity, resistance to fire, resilience to wind damage, tolerance to periodic drought (Dichoso 1984), and utility, economic and amenity values. Previous and ongoing work have concentrated on species adaptability trials, with emphasis on selected members of the genus *Acacia* and *Eucalyptus,* and some indigenous species (Krohn 1981). Field trials have been established on American Samoa, Guam, Pohnpei, and Yap and are planned for Rota and Palau. Because typhoons are a major threat to forest restoration, especially on Guam and Rota, any species that have proven successful in severe wind-prone areas merit serious consideration. These include *Acacia auriculiformis, Albizia lebbek, Casuarina equisetifolia, Celtis formosana, Hibiscus tiliaceus,* and *Leucaena leucocephala* (Kan and Hu 1987;

Quintana 1986). Although some of these trees may not produce all of the forest values desired, they may provide the toe-hold needed to initiate reestablishment of forest cover on very degraded sites.

In addition to species evaluation per se, work is needed on methods of type conversion that foster rapid tree growth and the "capture" of the site. Techniques are also needed to slow soil loss on severely eroding sites and to limit the spread of wildfire. Such research must therefore consider economical methods of site or tree spot preparation, control of competing vegetation, soil amendments (e.g., lime and fertilizer applications), planting design or arrangement, and possibly physical barriers to limit erosion.

Subsequent sections of this report describe needed research on basic ecology, soil properties, and silvicultural practices that support and complement watershed restoration work.

Forest Restoration in Secondary Vegetation Areas

Secondary vegetation has become established over substantial areas of some islands *(table 2)*; this land class is somewhat intermediate between the forest and non-forest land classes, and it includes a variety of fast-growing "weedy" trees, shrubs, and lianas. Common trees include *Bambusa* spp*., Cassia* spp*., Casuarina equisetifolia, Hibiscus tiliaceus, Leucaena leucocephala,* and *Macaranga carolinensis* (Cole and others 1987; Falanruw and others 1987a; MacLean and others 1986). Nearly one-half of Guam is covered by secondary vegetation, including "tangan-tangan" *(Leucaena leucocephala)* that was aerially seeded in 1947 to help restore watersheds devastated during World War II (Office of Technology Assessment 1984; Whitesell and others 1984). There are also significant areas of secondary vegetation in the Northern Marian Islands as well as on Palau, Yap, Pohnpei, and Kosrae. In some instances, such lands may represent former garden sites in the fallow stage (Falanruw 1991; Falanruw and others 1987a); the most extensive areas, however, probably represent land cleared for commercial agricultural production during occupations by the Germans and Japanese and burned over periodically ever since. In essence, these lands have been abandoned and are relatively unproductive.

Those islands with extensive areas of secondary vegetation have the best opportunities to meet local needs for fuel, fiber, and wood, by restoring or developing productive forests on these sites. These are also the most logical areas on which to establish and develop commercial forest plantations, including those aimed at producing fuelwood and craftwood. The general research need is to develop techniques for accelerating the development of upland forest stands in these areas. Ideally, such development can be pursued with the "aid" of existing vegetation, i.e., without clearing and completely replanting the area (see, for example, Lugo 1988). Information is needed to identify species, both native and introduced,

- to be favored or retained in any manipulation of existing vegetation,
- to be controlled so that they do not compete with and unduly hinder growth of desired species, and
- to be interplanted or underplanted to enrich the existing vegetation.

Studies must therefore be conducted on: (1) response of existing desired species to release, (2) recovery and the regrowth of competing species after control measures, and (3) performance of indigenous and introduced trees planted within the natural or modified environment of secondary vegetation. Work on plantation establishment and on approaches that integrate reforestation with agroforestry (Zabala and others 1986) and "swidden" (shifting, nature intensive) agriculture (Falanruw 1991) is also needed.

Land occupied by secondary vegetation is extensive on Guam, Babelthuap (Palau), Pohnpei, and Yap, and local foresters consider forest restoration in such areas to be of high priority (Noquez 1988). Because restoration studies will re-0quire keen observation and frequent measurement, initial work is best planned and conducted cooperatively with resource people on these islands. As techniques are developed, they can be tested and refined on other islands. Research on basic forest ecology and silvicultural systems will support work on forest restoration.

Basic Forest Ecology

Knowledge of the basic silvics of forest trees and stands is the biological foundation for management and utilization of productive forests, for restoration and preservation of endangered trees and stands, and for the reclamation of degraded sites. Unfortunately, information concerning native tree species is very limited. General information exists for some of the introduced species (e.g., *Pterocarpus indicus,* Wong 1982), but it was developed in other regions and must be validated and refined for Micronesian and American Samoan habitats. Information on plant population dynamics and patterns of vegetation succession is needed; such work has been done for the Kolombangara rain forest in the western Solomon Islands (Whitmore 1989), but most studies have been conducted in the tropics of Central and South America (Barton and others 1989; Ewel 1980).

Data are also needed on reproductive biology and genetic variation, including the phenology of flowering, fruiting, and seeding. Preliminary work on phenology of some species indigenous to Micronesia and American Samoa was done in the Solomon Islands *(Campnosperma, Terminalia,* and *Calophyllum)* by the Solomon Islands Forestry Division (S. I. Forestry Division 1981), and studies in collection, processing, and storage of *Campnosperma brevipetiolata* seed were conducted (Chaplin 1988a). Recently, however, the emphasis has shifted in the Solomons to plantations of introduced species *(Gmelina arborea* and *Swietenia macrophylla),* and study of native species has been dropped (Chaplin 1988b). Information is needed on the requirements for seed germination and successful seedling establishment in natural stands, including the role of buried seed (Hopkins and Graham 1987; Putz and Appanah 1987). And

work must be done on patterns and rates of primary and secondary growth of the major species, over a range of site conditions. Information on cambial growth was obtained effectively with aluminum dendrometer bands in lowland forest in Costa Rica (Hazlett 1987).

Much of this proposed research could be centered on a selected subset of the permanent sample plots established in conjunction with vegetation surveys and timber resource inventories (e.g., phenology and growth rates). Other work on characteristics of seed germination and vegetative reproduction can be done under controlled conditions in greenhouses and lathhouses, in collaboration with workers at various educational institutions and resource agencies throughout the Pacific Islands. Initial work should be focused on the native and introduced species and genera of greatest importance, notably *Campnosperma, Elaeocarpus, Terminalia Acacia, Pterocarpus,* and *Swietenia,* but information on many other species, including those listed in *table 3,* is also needed.

Soil Properties, Nutrient Cycling, and Fertilizer Application

Soil surveys have been published for most of the areas occupied by upland forests in American Samoa (Nakamura 1984) and Micronesia: Guam (Young 1988) and the Northern Mariana Islands (Young 1989), Palau (Smith 1983a), Yap (Smith 1983b), Chuuk (Laird 1983a), Pohnpei (Laird 1982), and Kosrae (Laird 1983b). In an effort to detect patterns between soil properties and existing vegetation, one study examined the relationship between general vegetation types and acidity classes of major soils (Falanruw and others 1987a). No patterns were identified at that level of resolution, but correlations certainly exist between soil characteristics and the presence or performance of individual plant species, or both. Comprehensive comparisons between soil properties in grassland/savanna areas and adjacent areas occupied by secondary vegetation and upland forest are particularly needed. Falanruw (1991) has speculated that the grassland/savanna areas on Yap were originally cleared of forest to produce food during periods of high human populations; subsequently, garden plots were abandoned and vegetative succession to forest has "stalled." In addition to repeated fires (discussed in a previous section), several soil and plant processes may be involved: developing hardpans, decreased transpiration (Sanchez 1976), reduced infiltration (Daubenmire 1972; Lal and others 1975), higher evaporation, and lowered rate of nutrient cycling (Budowski 1956). Such effects would result in periods of both waterlogging and extreme drought (Komkris 1978) and in low soil fertility (Budowski 1956), thus severely limiting the natural reestablishment of forest cover. A better understanding of soil-related differences among vegetative types as well as identifying the factors that limit tree growth in the Micronesian environment will aid the development of rehabilitation techniques and increase the successful selection of tree species for the reforestation of savanna/grassland areas.

Studies of plant-related processes, such as internal nutrient cycling and nutrient returns through litterfall, are also needed. Furthermore, comparisons among forested sites of similar species composition but contrasting productivity are in order, once productivity differences have been identified (see section on Forest Inventory and Productivity Assessment). Finally, techniques for improving and maintaining soil fertility should be developed and evaluated. Such research should include nitrogen-fixing shrubs and trees for use in mixed species plantations (DeBell and others 1987, 1989) and as green mulches (e.g., *Flemingia macrophylla*) *as* well as chemical fertilizers.

Damaging Agents

Several agents threaten existing upland forests and hinder attempts to restore tree cover to non-forested areas throughout the Pacific Islands. These agents include fire, vandalism, typhoons, salt spray, drought, insects, diseases, water buffalo, deer, goats, and various grasses, herbs, and lianas that suppress growth of young trees. Work is needed to define problems and their causes and to develop approaches to avoid or overcome such problems. Research should include:

- investigation of the extensive top die-back of many trees on Rota
- delineation of sites prone to exposure to, or sheltered from, typhoon damage
- evaluation of resistance of various tree species to fire, drought, and wind damage
- development of biological and other control measures to limit the establishment and growth of competing vegetation (e.g., "chain-of-love" and "mile-a-minute" vines).

Forest Inventory and Productivity Assessment

Data on inventory and growth of standing timber are necessary for sustained yield management. They will also be useful background information for restoration work. Timber inventories are available for American Samoa (Cole and others 1988), Federated States of Micronesia---Kosrae, Pohnpei, Truk, and Yap (MacLean and others 1988b), and Babelthuap Island in the Republic of Palau (MacLean and others 1988a). A similar inventory is needed on Rota, Commonwealth of the Northern Marian Islands. Eventually such inventories should be expanded to include other forest resources on all islands.

Few data are available on growth of the upland forests, but remeasurement of inventory plots established during the 1983-1986 period on the above-mentioned islands will provide some information. Specific studies, however, are needed to relate habitat characteristics (soil, microclimate, and species composition) of upland forest stands to standing volumes and current growth rates. Such studies can be overlaid on the existing network of inventory plots on several islands; for example, a subset of contrasting plots might be selected for characterization and evaluation, including measurement of periodic diameter growth using dendrometer bands.

Plantation forests (other than coconut palms, *Cocos nucifera*) are few in Micronesia, but some are impressive in apparent productivity and potential utility for local subsistence needs as well as a potential economic crop. Examples include big-leaf mahogany *(Swietenia macrophylla)* plantings on Guam, Yap, Palau, and Pohnpei and narra *(Pterocarpus indicus)* plantings on Pohnpei. Moreover, the rehabilitation of grassland/savanna areas and of some secondary vegetation areas will result in substantial areas of forest plantations. The location of existing plantations should be recorded, and permanent measurement plots should be established to determine quantity and quality of wood and wildlife habitat produced in such plantings.

Volume tables and site index curves are needed for mahogany, *Acacia* spp., and most of the native species. Provisional site index curves for *Campnosperma, Gmelina,* and *Terminalia* were developed from Solomon Island plantations (Neumann 1988b) and should be evaluated for use in Micronesia. Similarly, the applicability in Micronesia of the volume table for *Campnosperma brevipetiolata* developed in the Solomon Islands (Neumann 1988a) merits testing.

Silvicultural Systems

The upland forests of Micronesia are essentially unmanaged, and little specific information on applied silviculture exists. Research is needed to develop cultural practices and silvicultural systems for both native upland forests and plantations of both native and introduced tree species. Essential background for such development includes work on basic forest ecology as well as most of the topics discussed previously in other sections. But work on several additional topics is also required.

Silvicultural research in Micronesia and American Samoa should be preceded by a thorough literature search and review of past work pertaining to upland tropical forests and to the major native and introduced species. Ideally, this review should include visits to sites and institutions where the most pertinent research has been and is being done (e.g., the Solomon Islands Forestry Research Station, Munda). Our limited search indicated that related work has been conducted on nursery techniques and forest establishment practices (Armitage and Beveridge 1984; Chaplin 1984; Wilson 1985, 1986), species selection and evaluation (Chaplin 1988b; Solomon Islands Forestry Division 1978), and spacing (Thomson 1980).

Additional studies are needed to refine nursery procedures, outplanting techniques, fertilizer prescriptions, methods for weed control, and guidelines on density management and rotation age. In addition to research on specific cultural practices, general studies of regeneration and succession after various types of harvest cutting are needed.

For numerous social, economic, and ecological reasons, some form of partial cutting is usually more appropriate than clearcutting in tropical forests throughout the world (cf. de Graaf 1986; Thang 1987). This will likely be true also for the native upland forests and perhaps some of the plantation forests in the Pacific Islands. Some excellent near-term opportunities exist for collection of data pertinent to such issues. Several recently harvested areas exist on Palau and Pohnpei where regrowth of the forests can be assessed. Such assessments should include descriptions of the previous forest cover (from stump observations), residual stand, and the composition and rate of growth of vegetation established after or released by the harvest cuts, or both. On Guam, casual observations indicated abundant reproduction of several age cohorts beneath a 64-year-old *Swietenia macrophylla* plantation. A detailed study of this stand and, if possible, a historical reconstruction of its development would provide useful data for developing silvicultural options for this species. Finally, many possibilities exist to study the development of forest vegetation in gaps of various sizes (naturally existing or specifically created) in the upland forest types. Such work should be done on cutover permanent sample plots and in proximity to undisturbed permanent plots wherever possible.

Valuation of Forest Products and Services

Lack of information and appreciation for the value of products and services provided by upland forests is one of the greatest obstacles to wise use and management of forest resources in Micronesia and American Samoa. Indications of inadequate understanding abound. They are apparent in the multitude of incendiary fires on many islands; the minimal investment in fire detection and suppression---even on military lands on Guam, where one would expect funds and equipment to be readily available; and in the planned development of golf courses on portions of significant water catchments on Rota.

There is a need for a sound and broadly-considered valuation of forest products and services, specific to the Pacific Islands environments. Special attention should be given to nontimber products (Kerr 1991; Olsson 1991), to those uses and values that extend far beyond the forest boundary, and to negative impacts (e.g., silting of marine habitats or reductions in quantity and quality of potable water) that can result from inappropriate forest practices and extensive development or removal of forest cover. Such assessments should be economic in the broadest social sense, not merely financial analyses. Matters of long-term sustainability, including equity and externalities, should be considered (Bradley and Lothner 1989). Furthermore, the assessments should provide a useful framework for analyses of trade-offs and decisions regarding land use as well as investments specific to forest resources.

Threatened and Endangered Species

Many of the flora and fauna in the upland forests of Micronesia and American Samoa are endemic to individual islands or small groups of islands. Populations are often limited and may be threatened or endangered as development proceeds. Many species of birds are now rare in the few remaining forests of Guam because of predation by the introduced brown tree snake *(Boiga irregularis)* and perhaps because of losses associated with super-typhoons (> 175-mile-per-hour winds). The fruit bat *(Pteropus mariannus) is* threatened on several islands because of excessive harvest by hunters for the export markets (Falanruw

1988; Morse and others 1987). The tree species *Serianthes nelsonii* is considered endangered on Guam and on Rota as is *Osmoxylon marianensis,* found only on Rota.

Other species that are threatened or endangered in Micronesia should be determined and the remaining individuals and populations located. Some of these animals and plants may be essential to the restoration and long-term sustainability of upland forest ecosystems. Birds and fruit bats appear to play significant roles in the dissemination of seed of several tree species (e.g., Lambert 1989). Information is needed on habitat requirements and other factors that may limit the size and distribution of populations of threatened and endangered species. For some plant species, such as *Serianthes nelsonii* and *Osmoxylon marianensis,* the collection of seed and vegetative cuttings and establishment of *ex situ* populations and gene banks are appropriate. Such information (and, in some instances, the biological collections) will be essential for designing and implementing programs to restore the species to non-endangered status.

Description and Protection of Native Forest Habitats

On Kosrae, Palau, Rota, Pohnpei, and American Samoa, there are sizable areas of relatively undisturbed upland forest. However, little such habitat remains on Saipan, Guam, Yap, Chuuk, and on many other islands. Given the recent surge of tourist-related and urban development on some islands, it is important that remaining natural forest habitats be located and inventoried. Descriptions of the flora and fauna of such areas should be updated and their ecological roles defined. Because these areas provide a storehouse of information, as yet untapped, as well as a source of biological material for restoration and enrichment of other areas, a well-designed network of native forest habitats should be preserved and protected throughout the Pacific Islands. Such a network could be patterned after the Research Natural Area system (Franklin and Trappe 1968, Greene and others 1985) or similar programs in various states and countries (McNeely and others 1984). Action should, of course, be started first on those islands where remaining natural upland habitats are few and are most threatened by development.

Proposed Strategy and Focus for Research

The previous section contained a few suggestions regarding approaches to meeting information needs regarding specific problems, but some general matters also merit discussion. Often research in tropical forests has been conducted by non-resident scientists, many of whom did so out of personal interest in a relatively narrow subject for which they could obtain funds. In hindsight and in context of the broader need for information to protect and manage upland tropical forests, such efforts were often inefficient and frequently unsuccessful. Not only has past funding been inadequate in terms of the broader objective, but most activities commonly have suffered from shortcomings in identification and definition of problems; in prioritization, effectiveness, and continuity of scientific efforts; and in implementation of findings. Several basic considerations and strategies may be useful and should be considered as research and development efforts are expanded in Micronesia and American Samoa. We believe that research programs for upland forests should:

1. Obtain the aid of local educational, resource management, and political institutions in selecting and defining major problems for research and in developing alternative approaches to attack them. Indigenous knowledge related to both technical and societal aspects of the work must be tapped.

2. Involve strong collaboration with other Federal resource agencies-- particularly the USDA Agricultural Research Service and the USDA Soil Conservation Service; the USDI Fish and Wildlife Service; and the State and Private Forestry and International Forestry branches of USDA Forest Service--in research or development efforts wherever appropriate. Contacts and collaboration are also desirable with the Food and Agriculture Organization of United Nations, universities, the East-West Center, The Nature Conservancy, and agencies of other nations with interests in the tropical Pacific Region. Such cooperation will increase resources available for work on many of the problems and will also aid subsequent implementation.

3. Focus research activities in areas (islands) where the problem is greatest and where local infrastructures are most likely to ensure their continuity and success. Research on basic ecology and silvicultural systems for native forests is probably best concentrated on Palau and Pohnpei, whereas work on forest restoration and watershed rehabilitation could be centered on Guam and Yap.

4. Enlist and adequately recognize the assistance of local cooperators for protection and conduct of the studies. Many investigations will require long-term commitments to site protection and data-gathering, and much may be accomplished by local cooperators in the absence of the principal investigator.

We also support suggestions made by Lugo (1990) regarding strategies for mangrove research. These included the desirability of having a holistic focus, using ecosystem analysis techniques whenever appropriate, and selecting research sites based on a hierarchical habitat classification system. These strategies ensure that efforts are centered on the most common forest types, yet provide sufficient contrasts between environments to develop broad understanding of the relationships and findings. Geographic reference to specific habitats and measurement of environmental conditions also are essential for interpretation and extrapolation for management.

Finally, we offer two additional suggestions that are more specific than the foregoing. One suggestion arises from the need to provide some information quickly that will not only meet some near-term needs but also stimulate the interest and support of local institutions in research aimed at improving

management of the upland forest resource. Several opportunities for doing so were described in the previous section: (1) retrospective assessments of regeneration following recent harvesting activity on Pohnpei and Palau; (2) remeasurement and analysis of tree growth on the permanent inventory plots established 6 to 8 years ago throughout the islands; and (3) comprehensive evaluation of the few existing plantation forests. The second suggestion relates to both efficiency and the desirability of establishing a network of permanent plots (cf. Lugo 1990). We believe that new research should be tied as closely as possible to the previously mentioned permanent inventory plots. This existing network can provide the bases for a "jump-start" on certain problems and for a representative selection of sites of desired species composition. By concentrating studies of stand dynamics, productivity, nutrient cycling, and response to manipulation (e.g., gap studies) in or near these plots, we will foster opportunities for creative research by interdisciplinary scientific teams. These areas will also become the centers for subsequent educational and technology transfer activities.

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Conversion Chart

English to Metric

inches to millimeters	English x 25.40
inches to centimeters	English x 2.540
feet to meters	English x 0.305
miles to kilometers	English x 1.609
cubic feet to cubic meters	English x 0.0283
cubic feet per acre to cubic meters per hectare	English x 0.070
acres to hectares	English x 0.405

Appendix A

List of Persons Contacted on June 1991 Trip, by Island and Organization

Guam

Division of Forestry and Soils, Department of Agriculture
- Carlos Noquez, Territorial Forester
- Rudy Ando, In Charge, Forest Management
- David Limtiaco, In Charge, Fire Protection

Division of Wildlife, Department of Agriculture
- Gary Wiles, Research Biologist

University of Guam
- Donald Nafus, Entomologist
- Ilse Shriner, Entomologist

U.S. Department of Defense
- Andersen Air Force Base
- Heidi Hirsh, Base Conservationist

U.S. Naval Magazine
- Christopher Taylor

Palau

Agriculture Division, Department of Resources and Development
- Marcello Brel, Chief Forester

Rota

Division of Plant Industries, Department of Natural Resources
- Isaac Calvo, Forester

USDA Soil Conservation Service/Forest Service
- Robert Wescom (stationed in Guam)

Pohnpei

Forestry Division, Department of Conservation and Resource Surveillance
- Herson Anson, State Forester
- Andy Agrippa, Forestry Technician

College of Micronesia, Agriculture Experiment Station
- Anita Suta, Acting Director, Land Grant Program
- William Raynor, Agroforester

U.S. Department of State
- Ambassador Aurelia Erskine Brazeal

Pohnpei Agriculture and Trade School
- Kirk Richter, Agriculture Instructor

Yap

Pacific Southwest Research Station
- Marjorie Falanruw, Research Biologist
- Martin Faimau, Research Aid

Department of Resources and Development
- Jay Karmacharya, Horticulture Advisor
- Pius Liyagel, State Forester
- Mathius Kugmgar, Research Assistant

Touplay Agricultural Project
- Sister Marie May, Project Leader

Micronesia Maritime and Fisheries Academy
- Edmund Kalau, President, Pacific Missionary Aviation

The Forest Service, U.S. Department of Agriculture, is responsible for Federal leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands
- Cooperation with State and local governments, forest industries, and private landowners to help
  protect and manage non-Federal forest and associated range and watershed lands
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Research Station

- Represents the research branch of the Forest Service in California, Hawaii, American Samoa and the western Pacific.

United States
Department of
Agriculture

Forest Service

**Pacific Southwest
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General Technical
Report PSW-GTR-145

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