Guam's Forest Resources, 2002

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Abstract

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The Forest Inventory and Analysis Program collected, analyzed, and summarized field data on 46 forested plots on the island of Guam. Estimates of forest area, tree stem volume and biomass, the numbers of trees, tree damages, and the distribution of tree sizes were summarized for this statistical sample. Detailed tables and graphical highlights provide a summary of Guam's forest resources and a baseline from which to detect future change following remeasurement of the permanent field plots.

Keywords: Guam, biomass, damage, FIA, forest inventory, volume.

Summary

The Forest Inventory and Analysis (FIA) Program established a systematic sample of forest field plots on Guam to estimate forest area, tree stem volume and biomass, tree damages, and associated understory vegetation. Thirty-two permanent field plots were established in limestone forest and 14 in volcanic forest. Land cover was mapped from high-resolution satellite data and merged with the soil layer in a geographic information system to stratify the field sample. The forest area on Guam occupies approximately 63,830 acres, with limestone forest accounting for about 70 percent of that total. About 18 percent of Guam was classified as urban land and includes roads, towns, airstrips, and military facilities. We estimated gross tree stem volume to be about 91 million cubic feet, inclusive of all tree size classes. Aboveground stem weight for all trees greater than or equal to 5 inches in diameter at breast height was estimated to be about 1 million tons. About 21 percent of the trees sampled exhibited some form of physical damage. Of those damaged trees, evidence of decay was found in nearly one-third of the individuals. Physical breakage owing to weather and damage by falling trees were cited as the primary damaging agents in approximately 64 percent of the damage cases. The average number of tree species per sixth-acre plot was about four in both limestone and volcanic forest types. Forty-eight tree species and about 140 understory species were measured on 46 sixth-acre plots.

Introduction

This summary of forest resources on the island of Guam (fig. 1) was based on a forest inventory conducted in 2002 by the USDA Forest Service, Pacific Northwest Forest Inventory and Analysis Program (FIA) in cooperation with Pacific Island foresters. The key inventory objectives were to help answer local and national questions about the status and trends in tropical forested ecosystems and to share forestry skills among cultures and agencies. The fieldwork for this inventory was conducted by a multinational crew including students and foresters from Guam, foresters from American Samoa, and mainland U.S. foresters and ecologists.

This systematic, sample-based field inventory on Guam was the first of its kind to be conducted across the island to establish estimates for the area of forest types, tree size distribution, volume, biomass, and damages for living and dead trees. It was designed to provide resource managers with information about the current situation so they can better manage their forested and nonforested lands and, after remeasurement, better manage or mitigate any changes in the resource. Empirically based knowledge of the status and trends in forest vegetation can help managers plan sustainable supplies of wood, control invasive species, control erosion, and manage disturbances such as fire and animal damage.

Objectives

1. Estimate the area of forest land by forest type group and stand size class.
2. Estimate the volume, biomass, and carbon storage for tree species by diameter class.
3. Estimate the numbers of trees affected by damaging agents, such as insects and diseases, and estimate the number of dead trees.
4. Share measurement and analysis techniques among groups involved in the inventory.

Methods

Site Description

The island of Guam is the largest and farthest south in the north-south sweeping Marianas archipelago (fig. 1). The highest point on Guam is Mount Lamlam with an elevation of 1,332 feet. Guam is an unincorporated territory of the United States with significant income generated from tourism. The climate is tropical marine with little annual variation in temperature, but a pronounced dry season from January to June (fig. 2).

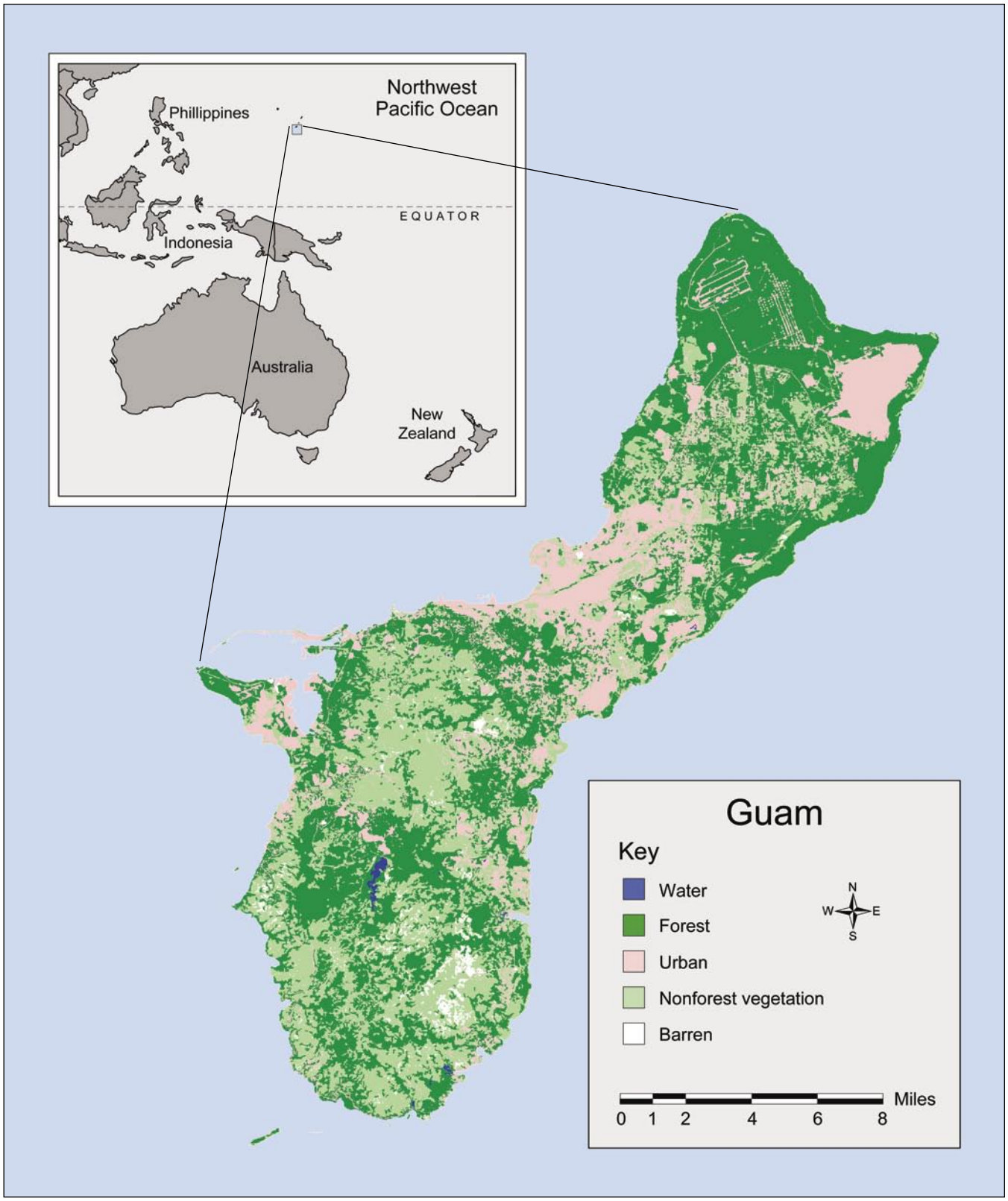

Figure 1—The unincorporated Territory of Guam is in the North Pacific Ocean approximately 1,600 miles east of Manila and 3,500 miles north of Melbourne, Australia.

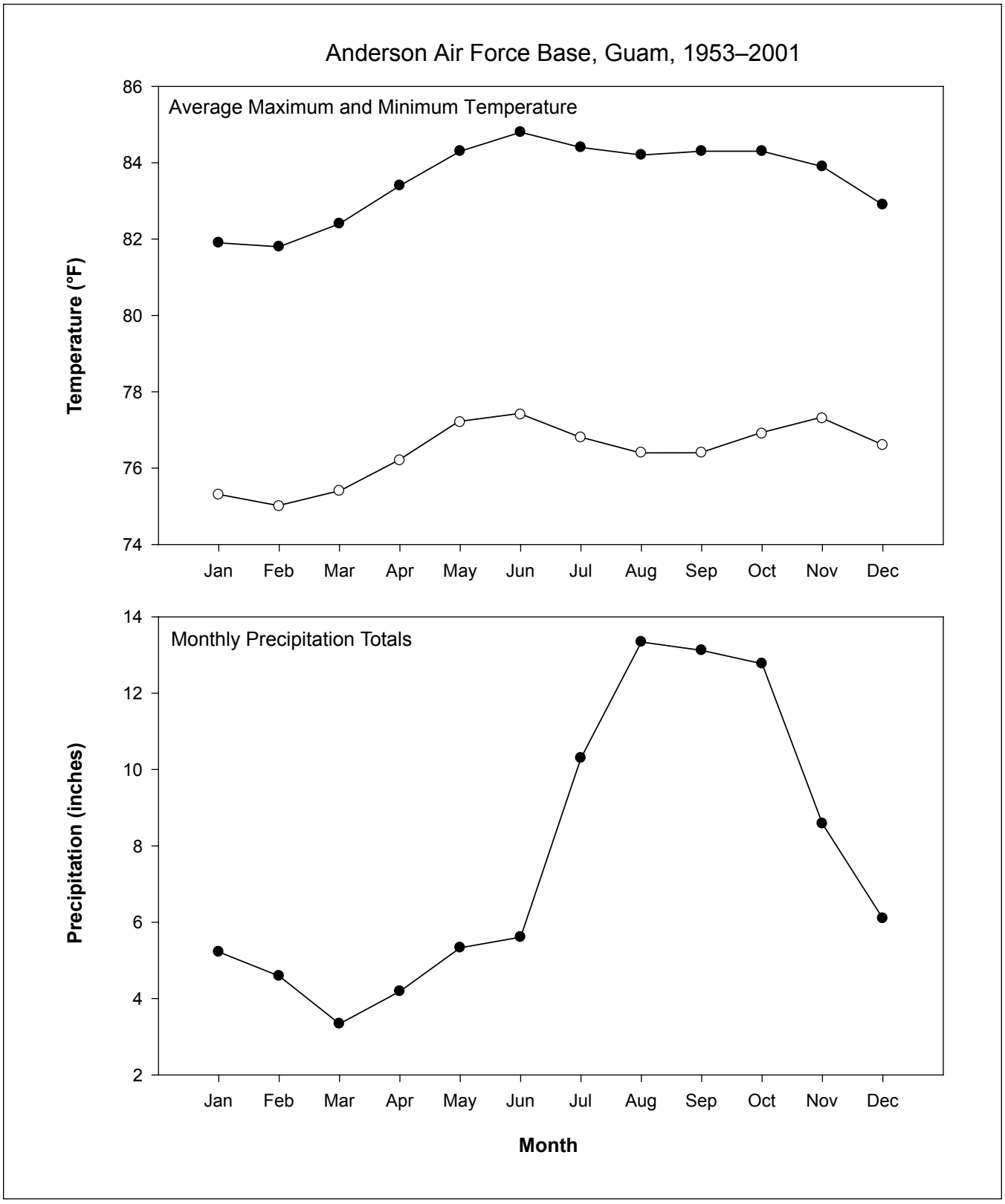

Figure 2—Average maximum and minimum temperature, and total monthly precipitation for Anderson Air Force Base, Guam. Note the pronounced seasonality in precipitation (Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?piande).

A significant portion of land on Guam is occupied by the U.S. military. On a portion of these lands, a system of refuges and wildlife reserves are overlain on the military lands. For example, Ritidian Point, approximately 22,500 acres at the northern tip of Guam, is administered by the U.S. Fish and Wildlife Service as a national wildlife refuge.

Significant disturbance agents have shaped vegetation in Guam, including frequent tropical storms and typhoons, human-caused grassland and forest fires, animal rooting, browsing and trampling, mass soil movements and erosion, non-native insects and pathogens, invasive weeds, historical military actions, and historical timber harvest.

Significant disturbance agents have shaped the vegetation on Guam. Humans and tropical storms continue changing forest structure and composition.

The northern half of the island is generally flat limestone plateau with abrupt dropoffs and cliffs toward the ocean. Locally the limestone can be strongly weathered into rugged karstic terrain. Soils are related to vegetation communities in Guam. The limestone soils in the north are covered with forest in areas not cultivated or urbanized. The southern part of the island features rolling to mountainous terrain in the deeply weathered volcanic soils. The volcanic soils on the southern half of Guam are covered primarily by grassland, with some ravine forest occurring in sheltered and leeward sites.

Vegetation Types

The vegetation of Guam was categorized (Mueller-Dombois and Fosberg 1998) according to the major underlying soil types: (1) northern limestone vegetation, and (2) southern volcanic vegetation. The limestone vegetation was further broken down into five classes by Fosberg (1960): *Artocarpus-Ficus* forest, *Mammea* forest, *Cordia* forest, *Merrilliodendron-Ficus* forest, and *Pandanus* forest. A brief description of each forest community follows. Pure examples of these forest types are now rare on Guam; instead these forests tend to be mixtures with secondary species predominating. The FIA inventory does not currently provide sufficient plot density to reliably classify vegetation types in these highly diverse tropical forests but provides plot-level data to help refine remotely sensed estimates of forest type acreage and developmental stage. Some of the forest types discussed below may not be represented in the plot-level information provided from this inventory owing to the systematic sampling design having missed the forest type. Ongoing mapping efforts will provide greater spatial detail and better refinement of forest types.

Limestone forest types

***Artocarpus-Ficus*—**
A widespread forest type on limestone in Guam with canopy dominants including *Artocarpus mariannensis* (breadfruit) and *Ficus prolixa* (banyan).

***Mammea* forest—**
Mueller-Dombois and Fosberg (1998) characterize this forest type as dominated by *Mammea odorata* and by its occurrence on the eastern escarpment of the northern limestone plateau.

***Cordia* forest—**
This is an open scrub-forest type on steep slopes and cliffs dominated by *Cordia subcordata* Lam.

***Merrilliodendron-Ficus* forest—**
Merrilliodendron megacarpum (Hemsley) Sleumer and *Ficus prolixa* dominate this tall forest type.

***Pandanus* forest—**
This moderate-height forest is dominated by *Pandanus tectorius*. Other common genera include *Flagellaria*, *Cestrum*, *Triphasia*, and *Nephrolepis* (Fosberg 1960).

Volcanic Types

The southern, volcanic half of the island is vegetated with a mix of grassland and patchy forest. The forest tends to follow topographic features, such as river drainages, sheltered depressions, and ravines. Grassland savannas are dominated by the dense, sharp-leaved *Miscanthus floridulus* (Labill.) Warb. ex K. Schum. & Laut. (swordgrass), and smaller areas of *Pennisetum polystachyon* (L.) J.A. Schultes (mission grass) and *Dimeria chloridiformis* (Gand.) K. Schum. & Laut. Common ravine forest trees include *Areca catechu*, (see table 1 for common names of trees) *Ficus prolixa*, *Glochidion mariana* Mueller-Arg., L., *Hibiscus tiliaceus*, *Pandanus tectorius*, *P. dubius* Sprengel, and *Premna serratifolia* L. (Fosberg 1960).

Low-lying, halophytic (sea-salt adapted) vegetation is found along beaches in the north and south, and may be composed solely of *Casuarina equisetifolia* or a mixture of species including *Casuarina*, *Cocos nucifera*, *Guettarda speciosa*, *Hernandia sonora*, *Pandanus tectorius*, *Scaevola taccada* (Gaertn.) Roxb., *Thespesia populnea* (L.) Soland. ex Correa, and *Tournefortia argentea* L. f. (Fosberg 1960). Areas of swamp, mangrove, and marsh are also found on Guam.

Table 1—Scientific and common names and estimated specific gravities[a] of species measured as trees on Guam

Scientific name	Common name	Specific gravity (for biomass)	Number measured
Adenanthera pavonina L.	kulalis	0.50	7
Aglaia mariannensis Merrill	mapuñao	.50	54
Annona reticulata L.	annonas	.50	8
Areca catechu L.	puguá	.50	9
Artocarpus altilis (Park.) Fosb.	lemai, breadfruit	.50	8
Artocarpus mariannensis Trec.	dugdug, Marianas breadfruit	.50	1
Averrhoa bilimbi L.	bilimbi, pikue	.50	9
Barringtonia asiatica (L.) Kurz	puting	.50	2
Barringtonia racemosa (L.) Spreng.	langaasag	.50	2
Bauhinia monandra Kurz	Saint Thomas tree, mariposa	.50	3
Calophyllum inophyllum L.	daok, Alexandrian laurel	.57	5
Cananga odorata (Lam.) Hook. f. & Thoms.	ilang-ilang	.29	7
Carica papaya L.	papaya	.50	23
Casuarina equisetifolia L.	gagu,australian pine	.84	9
Ceiba pentandra (L.) Gaertn.	algodon de manila	.23	1
Cerbera dilatata Markgraf	chuite	.50	19
Citrus aurantifolia (Christm.) Swingle	lime	.50	1
Cocos nucifera L.	niyok, coconut palm	.50	81
Cyathea lunulata (Forst. f.) Copel.	chacha, tree fern	.50	2
Cycas micronesica K.D. Hill	fandan (*C. circinalis* L.)	.50	112
Cynometra ramiflora L.	gulos	.70	5
Eugenia reinwardtiana (Benth.)	a'abang	.50	2
Eugenia thompsonii Merrill	atoto	.50	2
Ficus prolixa Forst. f.	nunu	.50	11
Ficus tinctoria Forst. f.	hoda, tagete	.50	2
Guamia mariannae Merrill	paipai	.50	47
Guettarda speciosa L.	pano	.50	1
Hernandia ovigera L.		.50	9
Hernandia sonora L.	nonak	.29	2
Heterospathe elata Scheffer	palma brava	.50	80
Hibiscus tiliaceus L.	sea-hibiscus, pago	.57	104
Inocarpus fagifer (Park.) Fosb.	budo buoy, Tahitian chestnut	.50	1
Intsia bijuga (Colebr.) O. Ktze.	ifit, ifil	.50	5
Kleinhovia hospita L.		.36	5
Leucaena leucocephala (Lam.) de Wit	tangantangan	.64	147
Macaranga thompsonii Merrill		.50	13
Mangifera indica L.	mango	.52	18
Morinda citrifolia L.	lada, Indian mulberry	.50	41
Neisosperma oppositifolia (Lam.) Fosb. & Sachet	faag	.50	3
Pandanus tectorius Park.	aggag	.50	61
Pipturus argenteus (Forst.) Wedd.	amahazan	.50	2
Polyscias grandifolia Volk.		.50	1
Premna obtusifolia R. Br.	ahgao	.50	50
Psidium guajava L.	guava, abas	.50	3
Spathodea campanulata Beauv.	African tulip tree	.25	4
Triphasia trifolia (Burm. f.) P. Wils.	limon de China	.50	38
Vitex parviflora Juss.		.70	92
Xylosma nelsonii Merrill		.50	1

[a] Specific gravity was used to calculate biomass and carbon mass.

Regions of barren, eroding soil are prevalent in the southern part of the island. The erosion problem is being addressed individually by multiple agencies and coordinated jointly through a multiagency consortium working on the vegetation strategy for southern Guam (Bell et al. 2002).

The FIA inventory design was adapted for the conditions and vegetation in Guam.

Field Methods

This inventory was based on the national FIA inventory design that was implemented across the mainland United States. Adaptations were made to the national design to use topography to define site productivity and to include additional branching and rooting forms, additional tree crown measurements, and special-interest species ranging from invasive plants to pathogens to culturally or economically important species of various life forms. In the mainland FIA Program, plots are spaced within forest land on a 3.3-mile grid. With the assistance of the Government of Guam, Division of Forestry, plots were spaced across all vegetation types at 1.9-mile intervals, yielding a triple intensification of the mainland inventory plot grid.

The FIA plot-cluster is composed of four 24-foot-radius subplots (fig. 3). Three of those subplots are equally spaced, as if on spokes of a wheel, around the central subplot. The distance from the middle of the central subplot to the middle of each subplot on the three spokes was 120 feet.

A variety of information was collected at the plot, subplot, and tree levels (USDA Forest Service 2002). Differences in forest-type conditions are also mapped. For example, roads that intersect subplots are mapped, as are clear boundaries in forest tree size classes. The primary variables collected include plot location, slope, aspect, elevation, subplot slope position and shape, tree species, diameters, heights, damages, branching and rooting forms, decay, epiphytic loadings, crown characteristics, tree locations, and regeneration information. The fieldwork for this inventory was performed February to April 2002, before the two major typhoons, Chata'an and Pongsona, struck the island in July and December of 2002, respectively.

Analysis Methods

The FIA estimates of forest land are based on a system that uses aerial photography or satellite imagery to define different types of land (strata) across the landscape. The simplest stratification is separating land into forest and nonforest strata. However, stratifications can be assisted or refined by using ancillary data such as topography, soil information, life zone or climatically based information, and prior inventories of vegetation groups.

The Guam stratification was conducted via a classification of 2002 IKONOS satellite data, masking out and replacing clouds by using aerial photography taken

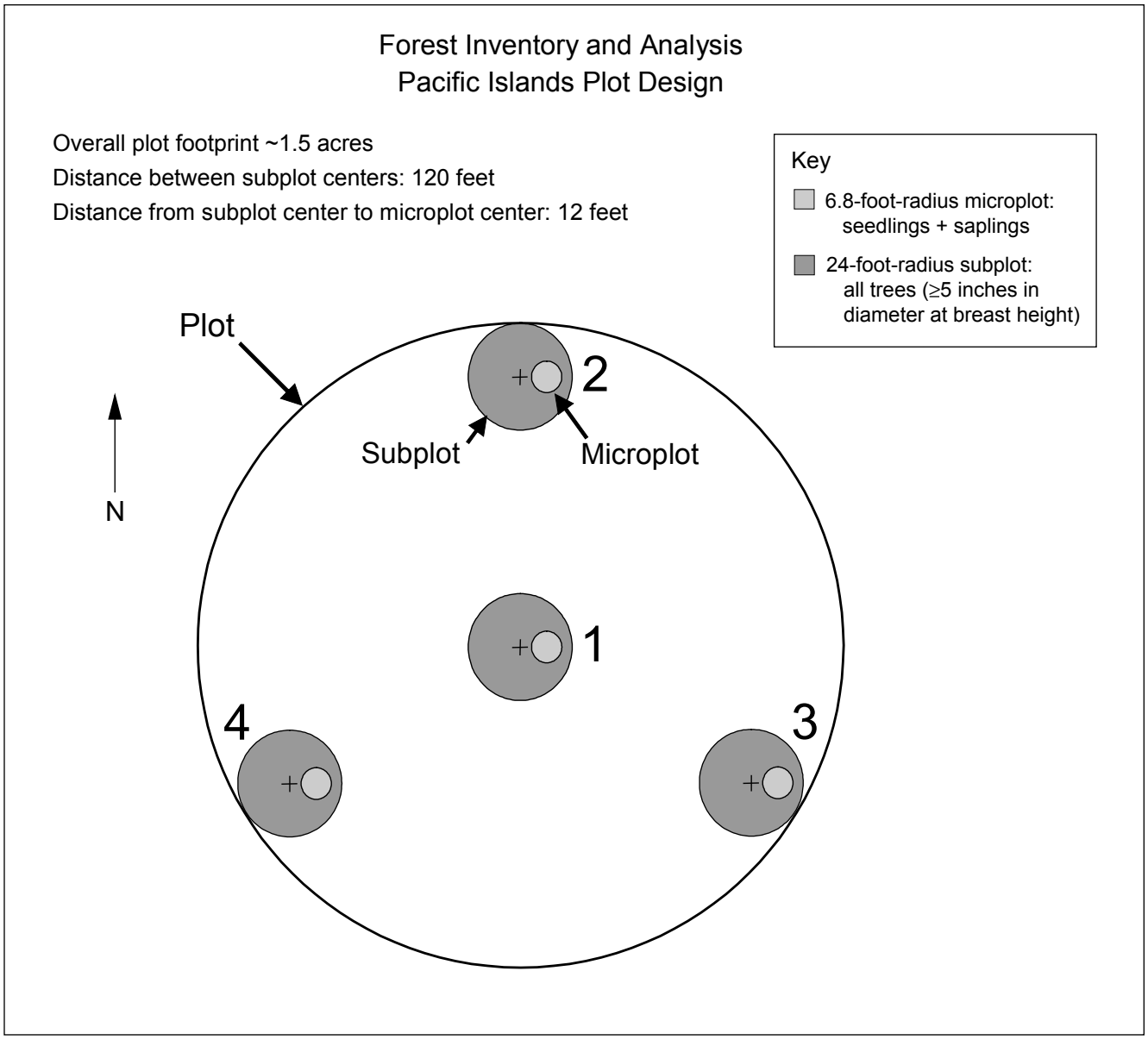

Figure 3—Forest Inventory and Analysis Pacific Islands plot design.

in 1994. The initial land cover classification divided the landscape into forest, urban, nonforest vegetation, barren, and water land types. At least 10 percent cover of trees was used as the basis for the forest land classification, and includes both agroforests and mangrove forests. Nonforest vegetation includes other vegetation types with less than 10 percent cover of trees. A geographic information system (GIS) was used to sum acreage for each type. Forest was further classified into volcanic and limestone forest types by overlaying a soils layer (USDA NRCS 1988) on the land-cover-classification layer in a GIS. We used the GIS to individually

sum the acreage of limestone and volcanic forest types. From this limestone/volcanic stratification, field plot condition types were expanded to the landscape level. The acreage each field plot represents was derived by dividing the total acreage of forest in each of the limestone and volcanic soil types by the number of field plots that fell within the geographic bounds of that specific type. Average stand size was expanded from the plots to the landscape level by using the same expansion factors. The forested areas on our initial land cover classification will be further refined into more detailed forest types in an ongoing project by the USDA Forest Service, Pacific Southwest Region, Remote Sensing Laboratory.

Wood volume was estimated for individual trees by using tree height and two stem diameter measurements. These measurements are expanded to tree-level volume estimates by using equations for sections of a cone. Both gross stem volume and net stem volume estimates were calculated. Net stem volume subtracts damage and rotten defects from gross stem volume. Biomass for individual tree stems was estimated by using the specific gravity for known species (31 out of 50 species measured on Guam have known specific gravities). For species where specific gravity was not known, an average specific gravity, according to forest type, was used. These estimates of aboveground tree biomass are derived from bole volume and include only biomass for the main stem, excluding branches, roots, and foliage.

An additive combination of relative density and relative basal area (importance value IV) was used to classify forest types and assess the species dominance in a stand. Traditional site productivity estimates require forest stand age, derived from the annual rings of forest trees. Because tropical trees do not produce consistent annual rings, a modified topographic relative moisture index (TRMI) (Parker 1982) was used as a proxy for site productivity. The TRMI used a weighted, additive combination of slope steepness, slope shape, and slope position to assess the potential moisture retention in a forested stand. The TRMI serves as a proxy for productivity until we can obtain growth rate data from remeasurement of these plots. We recognize moisture is not likely to be the only factor limiting tree growth and that an excess of moisture can be detrimental to tree growth.

Because tropical trees do not produce consistent annual rings, an index based on slope characteristics affecting moisture retention was used as a proxy for site productivity.

Reliability of FIA Data

The area of land cover types mapped from the IKONOS classification was assumed to be accurate and was used as the basis for the expansion of the numbers of trees, tree volume, and tree biomass from the plot scale to the forest-type scale. Possible sources of error not accounted for in our estimates include errors in the land cover map owing to incorrect interpretation of the image, errors from rounding when working with pixel-based imagery, and measurement errors on field plots. Standard

errors for the expansion of our estimates from field plots to the forested landscape were calculated according to the proportion of area occupied by either volcanic or limestone forest types. Volcanic and limestone forest areas were treated as known rather than estimated, and variance was calculated by using methods in Cochran (1977). Using one standard error as our basis for evaluation gives a 68 percent chance that the true total gross tree stem volume on Guam lies between 83,229,532 and 99,520,878 cubic feet. There is a 68-percent chance that the true number of trees (>1 inch diameter) on Guam lies within the range of 68,809,072 to 84,733,366.

Based on satellite imagery, we estimate that Guam is 48 percent forested.

Resource Highlights

Land Cover

Based on the IKONOS satellite imagery, we estimate that Guam is approximately 48 percent forested, with an additional 33 percent covered by grass and shrublands. Barren lands account for slightly over 1,500 acres (1 percent), and urban lands total approximately 24,000 acres (18 percent) (figs. 1 and 4, table 2).

Productivity

Forest land productivity was approximated as the potential of a site to retain moisture (TRMI) (Parker 1982) relative to that particular broad soil-based forest type (limestone vs. volcanic; table 3). Topography at each plot was used to rank sites within a forest type in terms of whether water would be expected to accumulate on or flow from the site. The limestone forests tended to occur on lands that would be classified predominantly (80 percent) as moderately high productivity (fig. 5). However, when basing potential productivity on topography, one must consider that limestone soil and parent material quickly drain water owing to high porosity. This may lead to an overestimate of productivity depending on the moisture-holding capacity of the soil. Sixty percent of the area of volcanic forest was classified as moderately high productivity or higher (fig. 6).

In Guam, trees tend to be relatively small owing to disturbance by typhoons and historical land use practices.

Forest Structure

Stand size class summarizes the predominant diameter of all live trees in a forested condition. In Guam, trees tend to be somewhat small in diameter, with the majority of forested area having trees in the 5- to 10.9-inch category (fig. 7). No stands were sampled in this inventory for the 20+ inch category. Such large-diameter stands are expected to be rare on Guam owing to frequent disturbance by typhoons.

The diameter distribution for trees on Guam follows a typical “reverse-J” pattern (fig. 8). More individuals are found in the smallest tree size classes (tables 4 and 5), which through time either grow into larger trees, die in the understory

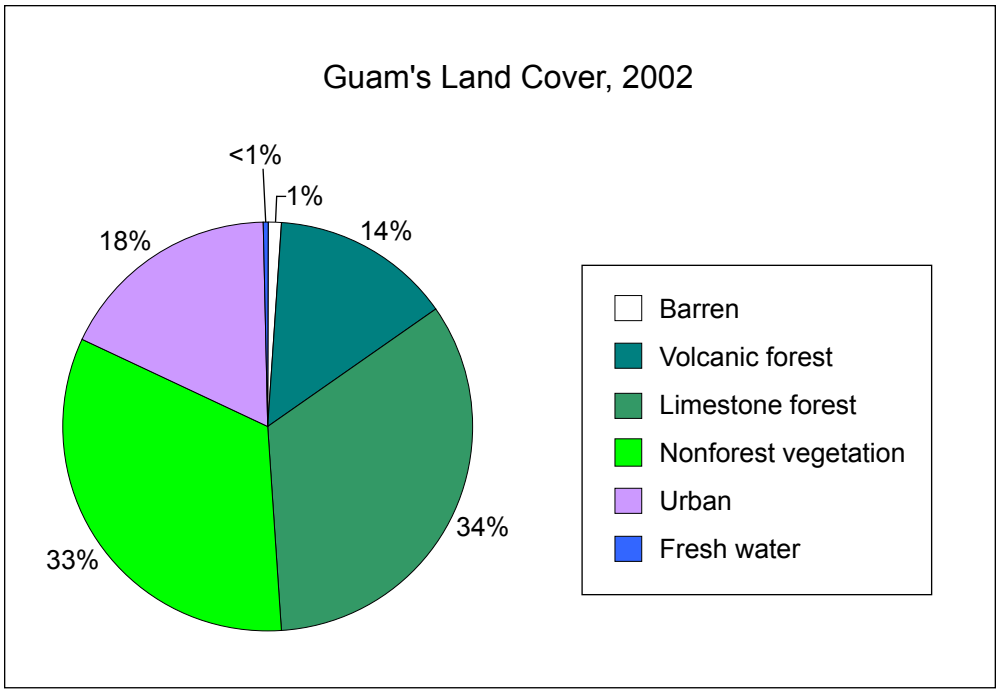

Figure 4—Land cover was mapped for Guam by using high-resolution satellite imagery. Guam is currently about 48 percent forested and 18 percent urban.

Table 2—Estimated land area by land status

Land status	Area
	Acres
Accessible forest land:	
Unreserved forest land—	
Limestone forest	44,704
Volcanic forest	19,129
Total unreserved	63,833
Reserved forest land	0
All accessible forest land	63,833
Nonforest and other area:	
Nonforest urban	23,956
Nonforest savanna or fernland	44,455
Barren lands	1,539
Area not classified	1,622
Water	255
All nonforest and other	71,827
Total forest and nonforest area	135,660
Area not included in field sample:	
Access denied	2,096
Hazardous conditions	1,716

Table 3—Estimated area of accessible forest land by forest-type group and productivity class

Forest-type group	Site productivity class[a]							All classes
	0–4.9	5–9.9	10–14.9	15–19.9	20–24.9	25–29.9	30–40	
					Acres			
Limestone forest	—	—	6,020	3,010	35,675	—	—	44,704
Volcanic/ravine forest	—	2,455	4,911	254	6,953	3,328	1,228	19,129
Total	—	2,455	10,930	3,264	42,628	3,328	1,228	63,833

[a]Classes are based on topographic relative moisture index. Higher numbers correspond to greater potential moisture retention on a site.

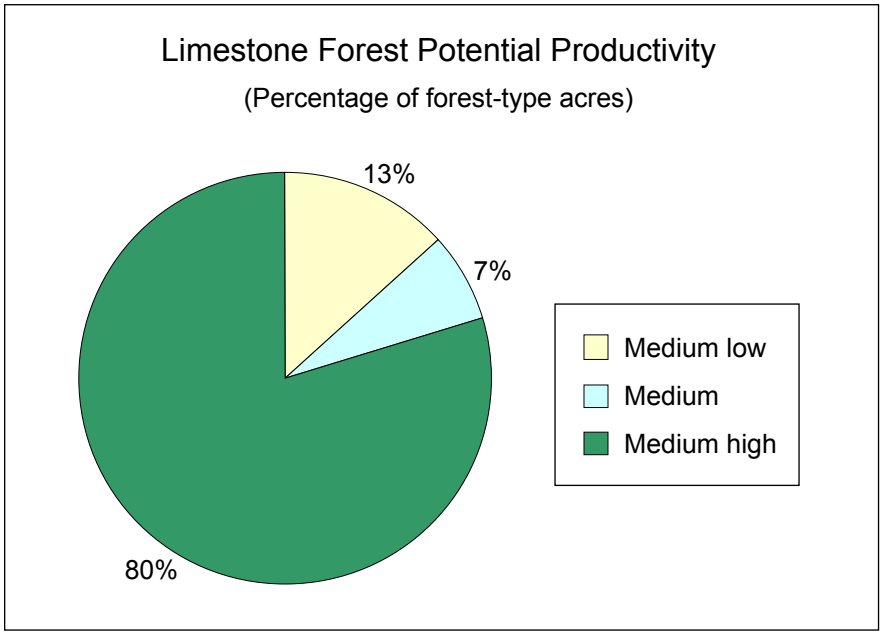

Figure 5—The majority of forest on limestone soils was estimated to be moderately high productivity. However, owing to the rapid runoff expected in karstic topography, productivity will depend greatly on the depth of soil present locally.

as other individuals outcompete them for space, or are killed by typhoon or other damaging agents. Likewise, cubic-foot volume (fig. 9, tables 6, 7, and 8), biomass (fig. 10, table 9), and carbon mass (table 10) follow similar trends, with the majority of each distributed among the smaller tree size classes. For trees greater than or equal to 5 inches in diameter, the mean tree height is approximately 25 feet with a standard deviation of 11.3 feet. Approximately 63 percent of the trees fall within the height range of 15 to 30 feet, and about 30 percent of the trees are greater than 30 feet tall.

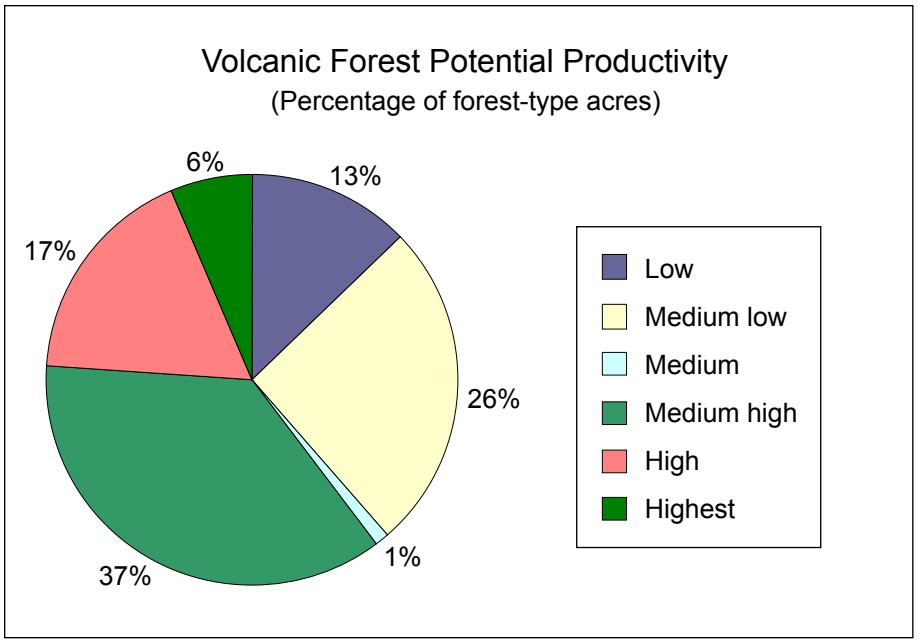

Figure 6—Much of the forest on volcanic soil occurs on steeper slopes. Productivity on these steeper slopes is expected to be lower than in areas where the moisture collects.

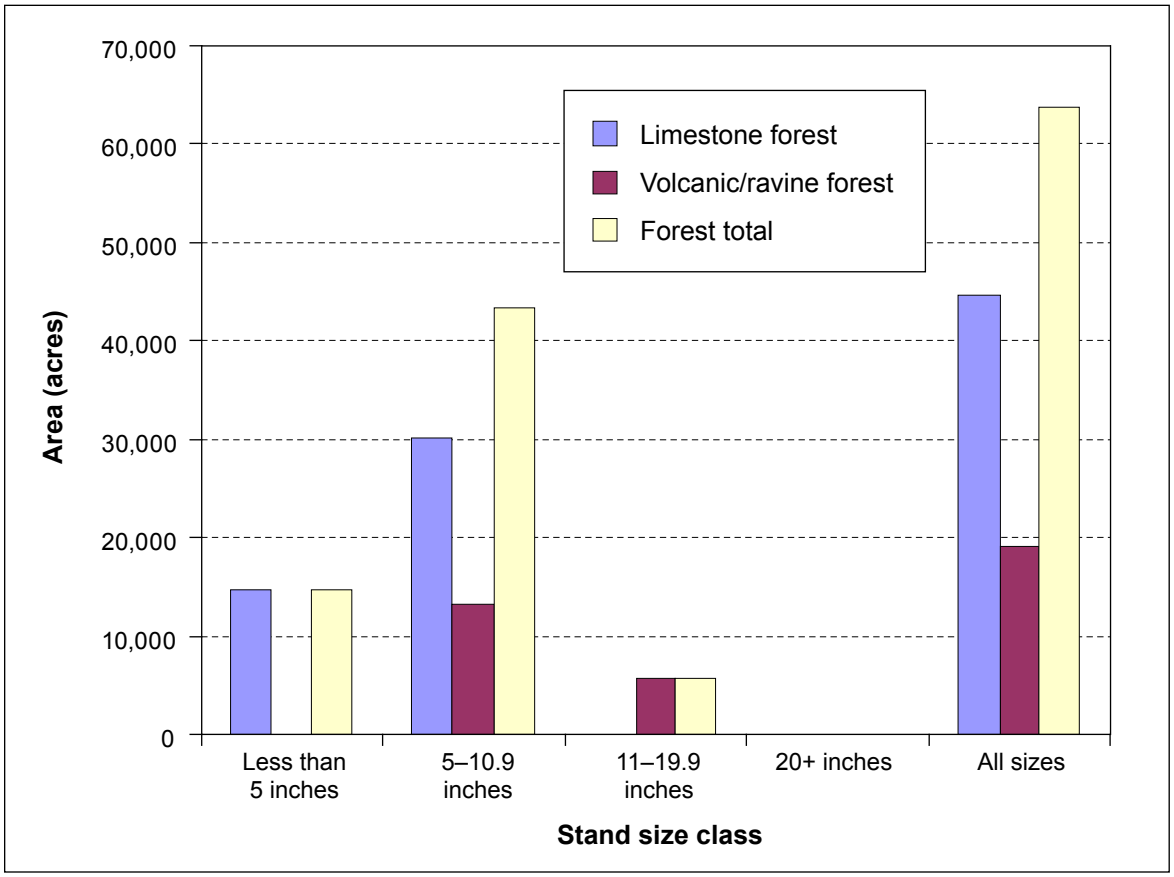

Figure 7—The majority of Guam's forests are characterized by small-diameter stands of trees.

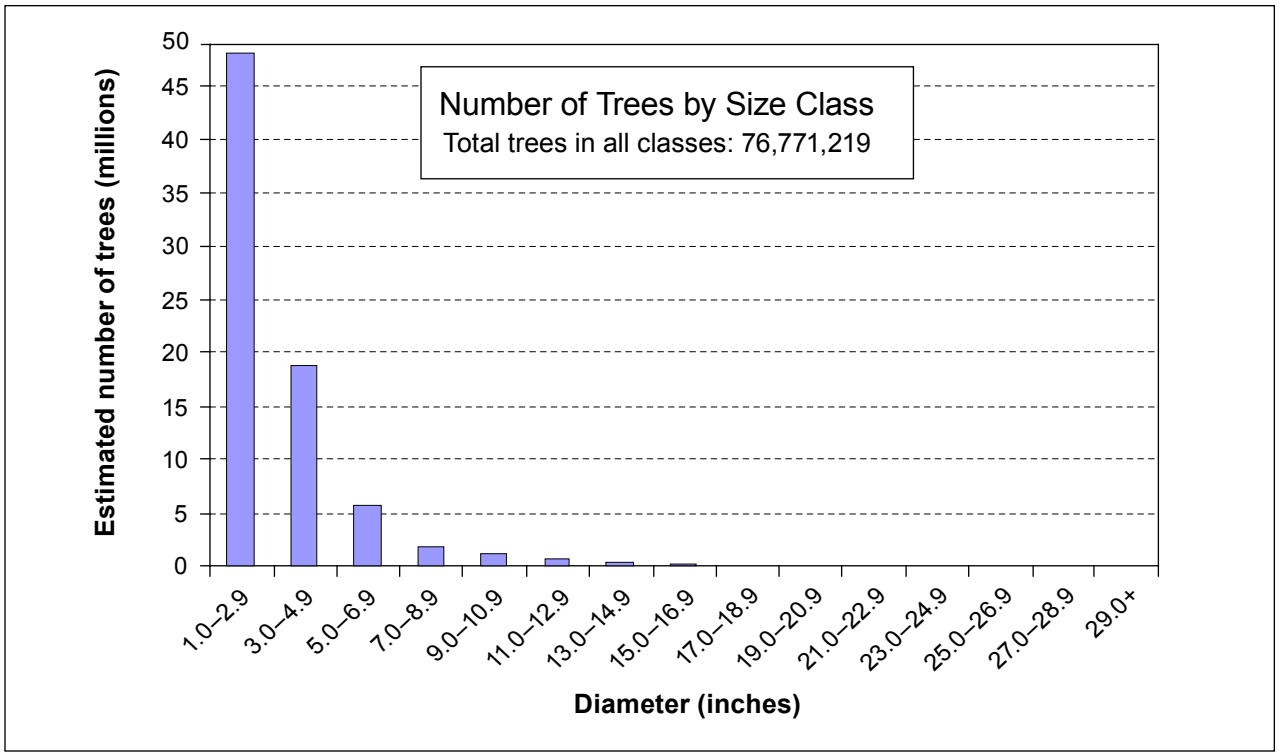

Figure 8—The distribution of number of trees by size class indicates Guam's forests tend to be dominated by smaller individuals.

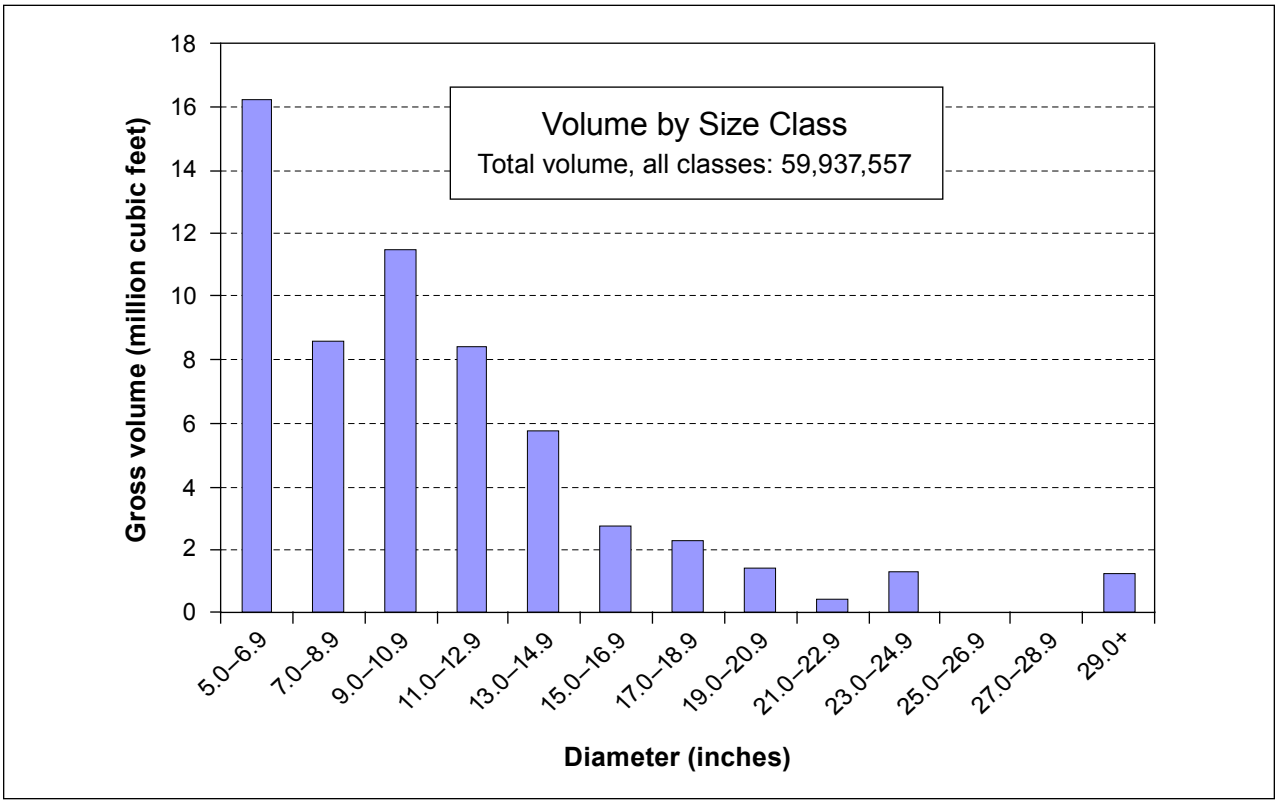

Figure 9—The woody stem volume for trees in Guam is concentrated in the smaller size classes.

Table 4—Estimated number of live trees on forest land by species group and diameter class

Species group	Diameter class (inches)										All classes
	1–2.9	3–4.9	5–6.9	7–8.9	9–10.9	11–12.9	13–14.9	15–16.9	17–18.9	19.0+	
	Number of trees										
Limestone forest type	42,779,542	14,079,343	3,622,623	1,275,163	652,072	231,848	130,414	57,962	28,981	72,452	62,930,401
Volcanic/ravine forest type	5,338,023	4,601,744	2,039,186	620,622	502,408	413,748	192,097	73,884	44,330	14,777	13,840,818
Total	48,117,565	18,681,087	5,661,809	1,895,785	1,154,480	645,596	322,512	131,846	73,311	87,229	76,771,219

Table 5—Estimated number of live trees on forest land by species and diameter class

Species	Diameter class (inches)													All classes
	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–22.9	23.0–24.9	25.0–26.9	27.0–28.9	29.0+	
	Number of trees													
Adenanthera pavonina	—	14,490	14,490	14,490	14,490	—	—	—	—	—	—	—	—	57,962
Aglaia mariannensis	260,829	28,981	—	—	—	—	—	—	—	—	—	—	—	289,810
Annona reticulata	86,943	—	—	—	—	—	—	—	—	—	—	—	—	86,943
Areca catechu	29,553	—	14,777	—	—	—	—	—	—	—	—	—	—	44,330
Artocarpus altilis	58,534	14,777	14,777	—	—	—	—	—	—	—	—	—	—	88,088
Artocarpus mariannensis	14,490	—	—	—	—	—	—	—	—	—	—	—	—	14,490
Averrhoa bilimbi	57,962	—	—	—	—	—	—	—	—	—	—	—	—	57,962
Barringtonia asiatica	—	14,490	—	—	—	—	—	—	—	14,490	—	—	—	28,981
Barringtonia racemosa	14,777	—	—	—	14,777	—	—	—	—	—	—	—	—	29,553
Calophyllum inophyllum	44,330	—	—	—	—	—	—	—	—	—	—	—	—	44,330
Cananga odorata	—	—	—	—	—	—	14,490	—	—	—	—	—	—	14,490
Carica papaya	43,471	43,471	14,490	—	—	—	—	—	—	—	—	—	—	101,433
Casuarina equisetifolia	43,471	43,471	14,490	14,490	—	—	—	—	—	—	—	—	—	115,924
Ceiba pentandra	—	14,490	—	—	—	—	—	—	—	—	—	—	—	14,490
Cerbera dilatata	101,433	28,981	28,981	—	—	—	—	—	—	—	—	—	—	159,395
Cocos nucifera	43,758	117,927	498,974	339,292	132,990	14,777	14,777	—	—	—	—	—	—	1,162,494
Cyathea lunulata	14,777	14,777	—	—	—	—	—	—	—	—	—	—	—	29,553
Cycas micronesica	900,700	510,316	117,069	28,981	14,490	—	—	—	—	—	—	—	—	1,571,556
Eugenia thompsonii	29,553	—	—	—	—	—	—	—	—	—	—	—	—	29,553
Ficus prolixa	43,471	—	14,490	—	—	44,044	14,777	—	—	—	—	—	14,490	145,764
Ficus tinctoria	14,490	14,490	—	—	—	—	—	—	—	—	—	—	—	28,981
Guamia mariannae	86,943	43,471	—	—	—	—	—	—	—	—	—	—	—	130,414
Hernandia ovigera	72,452	—	43,471	14,490	—	—	—	—	—	—	—	—	—	130,414
Hernandia sonora	14,490	—	14,490	—	—	—	—	—	—	—	—	—	—	28,981
Heterospathe elata	1,075,552	—	—	—	—	—	—	—	—	—	—	—	—	1,075,552
Hibiscus tiliaceus	437,291	115,924	14,490	—	—	—	—	—	—	—	—	—	—	567,705
Intsia bijuga	14,490	14,490	—	—	43,471	—	—	—	—	—	—	—	—	72,452
Kleinhovia hospita	43,471	14,490	—	—	—	—	—	—	—	—	—	—	—	57,962
Leucaena leucocephala	729,390	146,050	14,777	—	—	—	—	—	—	—	—	—	—	890,217
Macaranga thompsonii	43,471	57,962	28,981	43,471	—	14,490	—	—	—	—	—	—	—	188,376
Mangifera indica	—	29,553	14,777	88,660	44,330	29,553	14,777	14,777	—	—	—	—	—	236,427
Morinda citrifolia	58,821	—	—	—	—	—	—	—	—	—	—	—	—	58,821
Neisosperma oppositifolia	—	14,490	—	—	—	—	—	—	—	—	—	—	—	14,490
Pandanus tectorius	527,668	249,487	14,490	—	—	—	—	—	—	—	—	—	—	791,646
Premna obtusifolia	405,734	159,395	43,471	—	—	—	—	—	14,490	14,490	—	—	—	637,582
Spathodea campanulata	28,981	—	14,490	—	—	14,490	—	—	—	—	—	—	—	57,962
Vitex parviflora	306,018	189,808	218,502	101,720	57,962	14,490	14,490	—	—	—	—	—	—	902,990
Xylosma nelsonii	14,490	—	—	—	—	—	—	—	—	—	—	—	—	14,490
Total	5,661,809	1,895,785	1,154,480	645,596	322,512	131,846	73,311	29,267	14,490	28,981	—	—	14,490	9,972,568

Table 6—Estimated gross volume of all live trees on forest land by forest-type group and diameter class

Forest-type group	Diameter class (inches)				All sizes
	Less than 5	5–10.9	11–19.9	20+	
			Cubic feet		
Limestone forest type	25,000,018	22,194,860	8,278,410	3,937,467	59,410,755
Volcanic/ravine forest type	6,437,631	14,069,581	11,457,238		31,964,450
Total	31,437,648	36,264,441	19,735,649	3,937,467	91,375,205

Table 7—Estimated net volume of all live trees ≥5 inches in diameter on forest land by forest-type group and diameter class

Forest-type group	Diameter class (inches)			All sizes
	5–10.9	11–19.9	20+	
		Cubic feet		
Limestone forest type	21,467,757	8,248,484	3,756,956	33,473,197
Volcanic/ravine forest type	14,048,885	11,318,163		25,367,048
Total	35,516,642	19,566,647	3,756,956	58,840,245

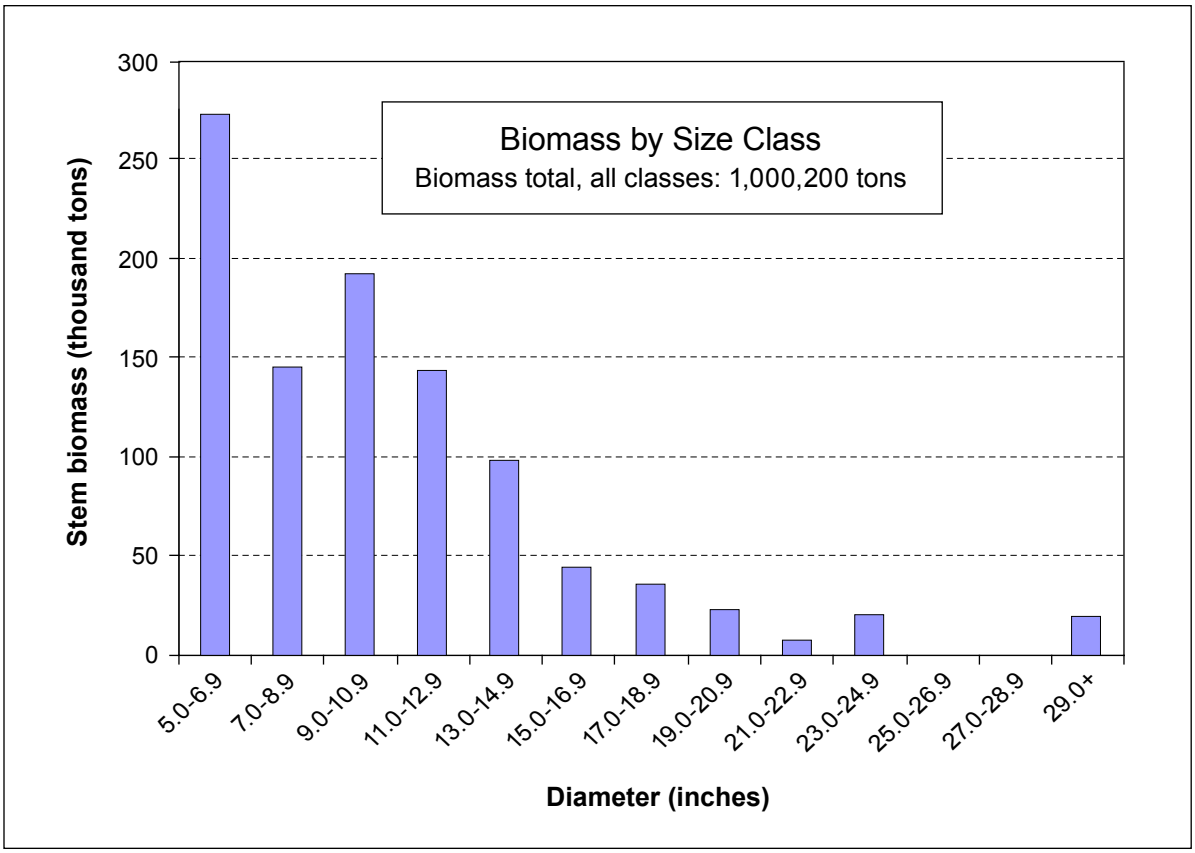

Figure 10—Small-diameter trees account for the greatest relative share of biomass in Guam's forests.

Table 8—Estimated gross volume of all live trees on forest land by species and diameter class

Species	Diameter class (inches)													All classes
	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–22.9	23.0–24.9	25.0–26.9	27.0–28.9	29.0+	
	Cubic feet													
Adenanthera pavonina	—	101,166	215,151	237,852	295,831	—	—	—	—	—	—	—	—	850,000
Aglaia mariannensis	745,310	147,832	—	—	—	—	—	—	—	—	—	—	—	893,142
Annona reticulata	243,248	—	—	—	—	—	—	—	—	—	—	—	—	243,248
Areca catechu	66,619	—	62,911	—	—	—	—	—	—	—	—	—	—	129,529
Artocarpus altilis	166,087	62,781	87,091	—	—	—	—	—	—	—	—	—	—	315,959
Artocarpus mariannensis	69,114	—	—	—	—	—	—	—	—	—	—	—	—	69,114
Averrhoa bilimbi	170,238	—	—	—	—	—	—	—	—	—	—	—	—	170,238
Barringtonia asiatica	—	94,617	—	—	—	—	—	—	—	678,079	—	—	—	772,696
Barringtonia racemosa	36,026	—	—	—	185,433	—	—	—	—	—	—	—	—	221,459
Calophyllum inophyllum	162,457	—	—	—	—	—	—	—	—	—	—	—	—	162,457
Cananga odorata	—	—	—	—	—	—	481,325	—	—	—	—	—	—	481,325
Carica papaya	97,698	153,709	147,836	—	—	—	—	—	—	—	—	—	—	399,244
Casuarina equisetifolia	158,514	212,708	156,081	171,682	—	—	—	—	—	—	—	—	—	698,985
Ceiba pentandra	—	68,581	—	—	—	—	—	—	—	—	—	—	—	68,581
Cerbera dilatata	324,750	168,655	212,986	—	—	—	—	—	—	—	—	—	—	706,391
Cocos nucifera	157,742	598,026	5,659,657	4,275,006	2,066,260	284,146	578,822	—	—	—	—	—	—	13,619,659
Cyathea lunulata	27,992	56,791	—	—	—	—	—	—	—	—	—	—	—	84,783
Cycas micronesica	1,735,701	1,810,718	724,419	265,754	165,066	—	—	—	—	—	—	—	—	4,701,658
Eugenia thompsonii	78,386	—	—	—	—	—	—	—	—	—	—	—	—	78,386
Ficus prolixa	258,381	—	251,358	—	—	685,362	210,436	936,398	—	—	—	—	1,238,105	3,580,041
Ficus tinctoria	42,561	71,029	—	—	—	—	—	—	—	—	—	—	—	113,590
Guamia mariannae	197,414	259,918	—	—	—	—	—	—	—	—	—	—	—	457,332
Hernandia ovigera	165,222	—	361,133	178,057	—	—	—	—	—	—	—	—	—	704,413
Hernandia sonora	65,398	—	115,645	—	—	—	—	—	—	—	—	—	—	181,043
Heterospathe elata	3,562,810	—	—	—	—	—	—	—	—	—	—	—	—	3,562,810
Hibiscus tiliaceus	1,233,493	610,807	81,339	—	—	—	—	—	—	—	—	—	—	1,925,638
Intsia bijuga	63,488	59,862	—	—	916,945	—	—	—	—	—	—	—	—	1,040,296
Kleinhovia hospita	126,462	83,586	—	—	—	—	—	—	—	—	—	—	—	210,048
Leucaena leucocephala	2,071,080	654,665	84,420	—	—	—	—	—	—	—	—	—	—	2,810,165
Macaranga thompsonii	128,274	343,322	274,918	567,175	—	256,535	—	—	—	—	—	—	—	1,570,224
Mangifera indica	—	109,580	192,508	1,284,968	945,215	746,063	473,038	520,927	—	—	—	—	—	4,272,299
Morinda citrifolia	167,806	—	—	—	—	—	—	—	—	—	—	—	—	167,806
Neisosperma oppositifolia	—	53,968	—	—	—	—	—	—	—	—	—	—	—	53,968
Pandanus tectorius	1,531,375	1,140,927	140,841	—	—	—	—	—	—	—	—	—	—	2,813,143
Premna obtusifolia	1,185,221	797,452	393,112	—	—	—	—	—	483,181	601,705	—	—	—	3,460,670
Spathodea campanulata	98,688	—	114,276	—	—	334,289	—	—	—	—	—	—	—	547,254
Vitex parviflora	1,040,617	938,346	2,161,915	1,444,560	1,181,825	457,650	525,425	—	—	—	—	—	—	7,750,339
Xylosma nelsonii	49,624	—	—	—	—	—	—	—	—	—	—	—	—	49,624
Total	16,227,799	8,599,046	11,437,596	8,425,054	5,756,576	2,764,045	2,269,047	1,457,325	483,181	1,279,783	—	—	1,238,105	59,937,557

Table 9—Estimated aboveground dry stem weight of all live trees on forest land by species and diameter class

Species	Diameter class (inches)													All classes
	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–22.9	23.0–24.9	25.0–26.9	27.0–28.9	29.0+	
	Tons													
Adenanthera pavonina	—	1,578	3,356	3,710	4,615	—	—	—	—	—	—	—	—	13,260
Aglaia mariannensis	11,627	2,306	—	—	—	—	—	—	—	—	—	—	—	13,933
Annona reticulata	3,795	—	—	—	—	—	—	—	—	—	—	—	—	3,795
Areca catechu	1,039	—	981	—	—	—	—	—	—	—	—	—	—	2,021
Artocarpus altilis	2,591	979	1,359	—	—	—	—	—	—	—	—	—	—	4,929
Artocarpus mariannensis	1,078	—	—	—	—	—	—	—	—	—	—	—	—	1,078
Averrhoa bilimbi	2,656	—	—	—	—	—	—	—	—	—	—	—	—	2,656
Barringtonia asiatica	—	1,476	—	—	—	—	—	—	—	10,578	—	—	—	12,054
Barringtonia racemosa	562	—	—	—	2,893	—	—	—	—	—	—	—	—	3,455
Calophyllum inophyllum	2,889	—	—	—	—	—	—	—	—	—	—	—	—	2,889
Cananga odorata	—	—	—	—	—	—	4,355	—	—	—	—	—	—	4,355
Carica papaya	1,524	2,398	2,306	—	—	—	—	—	—	—	—	—	—	6,228
Casuarina equisetifolia	4,154	5,575	4,091	4,499	—	—	—	—	—	—	—	—	—	18,319
Ceiba pentandra	—	492	—	—	—	—	—	—	—	—	—	—	—	492
Cerbera dilatata	5,066	2,631	3,323	—	—	—	—	—	—	—	—	—	—	11,020
Cocos nucifera	2,461	9,329	88,291	66,690	32,234	4,433	9,030	—	—	—	—	—	—	212,467
Cyathea lunulata	437	886	—	—	—	—	—	—	—	—	—	—	—	1,323
Cycas micronesica	27,077	28,247	11,301	4,146	2,575	—	—	—	—	—	—	—	—	73,346
Eugenia thompsonii	1,223	—	—	—	—	—	—	—	—	—	—	—	—	1,223
Ficus prolixa	4,031	—	3,921	—	—	10,692	3,283	14,608	—	—	—	—	19,314	55,849
Ficus tinctoria	664	1,108	—	—	—	—	—	—	—	—	—	—	—	1,772
Guamia mariannae	3,080	4,055	—	—	—	—	—	—	—	—	—	—	—	7,134
Hernandia ovigera	2,577	—	5,634	2,778	—	—	—	—	—	—	—	—	—	10,989
Hernandia sonora	592	—	1,046	—	—	—	—	—	—	—	—	—	—	1,638
Heterospathe elata	55,580	—	—	—	—	—	—	—	—	—	—	—	—	55,580
Hibiscus tiliaceus	21,936	10,863	1,447	—	—	—	—	—	—	—	—	—	—	34,246
Intsia bijuga	990	934	—	—	14,304	—	—	—	—	—	—	—	—	16,229
Kleinhovia hospita	1,420	939	—	—	—	—	—	—	—	—	—	—	—	2,359
Leucaena leucocephala	41,355	13,072	1,686	—	—	—	—	—	—	—	—	—	—	56,113
Macaranga thompsonii	2,001	5,356	4,289	8,848	—	4,002	—	—	—	—	—	—	—	24,496
Mangifera indica	—	1,778	3,123	20,847	15,335	12,104	7,675	8,452	—	—	—	—	—	69,314
Morinda citrifolia	2,618	—	—	—	—	—	—	—	—	—	—	—	—	2,618
Neisosperma oppositifolia	—	842	—	—	—	—	—	—	—	—	—	—	—	842
Pandanus tectorius	23,889	17,798	2,197	—	—	—	—	—	—	—	—	—	—	43,885
Premna obtusifolia	18,489	12,440	6,133	—	—	—	—	—	7,538	9,387	—	—	—	53,986
Spathodea campanulata	770	—	891	—	—	2,607	—	—	—	—	—	—	—	4,269
Vitex parviflora	22,727	20,493	47,216	31,549	25,811	9,995	11,475	—	—	—	—	—	—	169,267
Xylosma nelsonii	774	—	—	—	—	—	—	—	—	—	—	—	—	774
Total	271,673	145,576	192,590	143,068	97,767	43,833	35,817	23,059	7,538	19,965	—	—	19,314	1,000,200

Table 10—Estimated aboveground weight of carbon for stems of all live trees on forest land by species and diameter class

Species	Diameter class (inches)													All classes
	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–22.9	23.0–24.9	25.0–26.9	27.0–28.9	29.0+	
	Tons													
Adenanthera pavonina	—	773	1,645	1,818	2,261	—	—	—	—	—	—	—	—	6,497
Aglaia mariannensis	5,697	1,130	—	—	—	—	—	—	—	—	—	—	—	6,827
Annona reticulata	1,859	—	—	—	—	—	—	—	—	—	—	—	—	1,859
Areca catechu	509	—	481	—	—	—	—	—	—	—	—	—	—	990
Artocarpus altilis	1,270	—	666	—	—	—	—	—	—	—	—	—	—	2,415
Artocarpus mariannensis	528	—	—	—	—	—	—	—	—	—	—	—	—	528
Averrhoa bilimbi	1,301	—	—	—	—	—	—	—	—	—	—	—	—	1,301
Barringtonia asiatica	—	723	—	—	—	—	—	—	—	5,183	—	—	—	5,906
Barringtonia racemosa	275	—	—	—	1,417	—	—	—	—	—	—	—	—	1,693
Calophyllum inophyllum	1,416	—	—	—	—	—	—	—	—	—	—	—	—	1,416
Cananga odorata	—	—	—	—	—	—	2,134	—	—	—	—	—	—	2,134
Carica papaya	747	1,175	1,130	—	—	—	—	—	—	—	—	—	—	3,052
Casuarina equisetifolia	2,036	2,732	2,004	2,205	—	—	—	—	—	—	—	—	—	8,976
Ceiba pentandra	—	241	—	—	—	—	—	—	—	—	—	—	—	241
Cerbera dilatata	2,482	1,289	1,628	—	—	—	—	—	—	—	—	—	—	5,400
Cocos nucifera	1,206	4,571	43,262	32,678	15,794	2,172	4,425	—	—	—	—	—	—	104,109
Cyathea lunulata	214	434	—	—	—	—	—	—	—	—	—	—	—	648
Cycas micronesica	13,268	13,841	5,537	2,031	1,262	—	—	—	—	—	—	—	—	35,939
Eugenia thompsonii	599	—	—	—	—	—	—	—	—	—	—	—	—	599
Ficus prolixa	1,975	—	1,921	—	—	5,239	1,609	7,158	—	—	—	—	9,464	27,366
Ficus tinctoria	325	543	—	—	—	—	—	—	—	—	—	—	—	868
Guamia mariannae	1,509	1,987	—	—	—	—	—	—	—	—	—	—	—	3,496
Hernandia ovigera	1,263	—	2,761	1,361	—	—	—	—	—	—	—	—	—	5,385
Hernandia sonora	290	—	513	—	—	—	—	—	—	—	—	—	—	803
Heterospathe elata	27,234	—	—	—	—	—	—	—	—	—	—	—	—	27,234
Hibiscus tiliaceus	10,749	5,323	709	—	—	—	—	—	—	—	—	—	—	16,780
Intsia bijuga	485	458	—	—	7,009	—	—	—	—	—	—	—	—	7,952
Kleinhovia hospita	696	460	—	—	—	—	—	—	—	—	—	—	—	1,156
Leucaena leucocephala	20,264	6,405	826	—	—	—	—	—	—	—	—	—	—	27,496
Macaranga thompsonii	981	2,624	2,101	4,335	—	1,961	—	—	—	—	—	—	—	12,003
Mangifera indica	—	871	1,530	10,215	7,514	5,931	—	4,141	—	—	—	—	—	33,964
Morinda citrifolia	1,283	—	—	—	—	—	—	—	—	—	—	—	—	1,283
Neisosperma oppositifolia	—	413	—	—	—	—	—	—	—	—	—	—	—	413
Pandanus tectorius	11,706	8,721	1,077	—	—	—	—	—	—	—	—	—	—	21,504
Premna obtusifolia	9,060	6,096	3,005	—	—	—	—	—	3,693	4,599	—	—	—	26,453
Spathodea campanulata	377	—	437	—	—	1,278	—	—	—	—	—	—	—	2,092
Vitex parviflora	11,136	10,042	23,136	15,459	12,647	4,898	5,623	—	—	—	—	—	—	82,941
Xylosma nelsonii	379	—	—	—	—	—	—	—	—	—	—	—	—	379
Total	133,120	71,332	94,369	70,103	47,906	21,478	17,550	11,299	3,693	9,783	—	—	9,464	490,098

Number of Canopy and Understory Species

The field sample of this inventory considers both overstory and understory vegetation. Understory vegetation cover was surveyed on field plots for individual species that occupy at least 3 percent cover on an entire subplot (tables 11 and 12). Relatively rare species are not documented on plots unless they have been identified as a special-interest species by island foresters. More species were found in the limestone forest sample than in the volcanic forest sample (fig. 11). However, the limestone sample area was over twice the area of the volcanic forest sample, and the number of species found tends to increase with the area sampled. These species figures are only a rough estimate of cover and species counts for the most common plants. Stone (1971) details 931 species in the flora of Guam.

On a per-plot basis, using the sum of FIA subplot area of approximately one-sixth of an acre (summing four subplots at 24-foot radius = 7,238 square feet), the distribution of tree species numbers reveals a pattern of a relatively high number of species per plot (fig. 12). Plots where only one or two species are found are often plots dominated by the widespread *Hibiscus tiliaceus*, *Casuarina equisetifolia*, or the recently broadcast (aerial seeded after World War II) *Leucaena leucocephala*.

Tree Damage and Mortality

We estimate that about 20 percent of the individual trees on Guam have been damaged (table 13). These damages include mechanical damage from storms and people, diseases, insects, decay, and damage by other plant species. Approximately one-third of the damaged trees show signs of decay with visible growth of wood-rotting fungus (conks) (fig. 13).

Tree damages are categorized according to causal agents. Because a tree can exhibit secondary damages caused by another agent, we have classified damages according to frequency for the primary and secondary damage agents. Thirty-six percent of primary tree damages in Guam forests are attributed to weather (fig. 14). Damage caused by other vegetation, insects, and diseases follow in declining frequency for primary damage types. Insects frequently play a secondary role following damage or weakening by another damaging agent (fig. 15).

About 20 percent of the trees on Guam have been damaged—most from weather, other vegetation, and insects.

Tree damages can contribute to mortality at different rates for different species. Some species are more sensitive than others to insects, some to fungal, viral, or bacterial pathogens that gain entry into plant tissues through mechanical wounding. Overall, about 2 percent of the trees in our sample were dead. However, by species, the percentage dead ranges as high as 33 percent for breadfruit trees *(Artocarpus altilis*) in the inventory (fig. 16).

Table 11—Average nontree understory cover[a] on FIA field subplots by species and forest type

Species	Forest type	
	Limestone	Volcanic
	Percent	
Unknown	12	—
Abutilon indicum (L.) Sweet	—	3
Aeschynomene indica L.	—	10
Allophylus timoriensis (DC) Bl.	3	—
Alocasia macrorrhiza (L.) Schott	—	5
Antrophyum plantagineum (Cav.) Kaulf.	—	5
Antigonon leptopus Hook. & Arn.	20	17
Arundina graminifolia (D. Don) Hochr.	—	3
Asplenium laserpitifolium Lam.	—	7
Axonopus compressus (Sw.) Beauv.	9	15
Bambusa vulgaris Schrad. ex J.C. Wendl.	10	—
Belvisia spicata Safford	3	4
Bidens alba (L.) DC.	27	8
Blechum pyramidatum (Lam.) Urban	33	—
Bothriochloa pertusa (L.) A. Camus	—	32
Buddleja asiatica Lour.	5	—
Calopogonium mucunoides Desv.	11	5
Calyptocarpus vialis Less.	10	—
Cassytha filiformis L.	3	—
Centotheca lappacea (L.) Desv.	5	11
Centrosema pubescens Benth.	9	—
Chamaecrista nictitans (L.) Moench	—	3
Chamaesyce sp. S.F. Gray	3	—
Chamaesyce hirta (L.) Millsp.	—	3
Chamaesyce hypericifolia (L.) Millsp.	3	—
Chloris barbata Sw.	—	8
Chloris radiata (L.) Sw.	30	—
Chromolaena odorata (L.) King & H.E. Robins.	13	12
Clerodendrum inerme (L.) Gaertn.	5	—
Colubrina asiatica (L.) Brongn.	28	—
Conyza canadensis (L.) Cronq.	4	—
Cynodon dactylon (L.) Pers.	10	3
Cyperus ligularis L.	3	—
Davallia solida (Forst.) Sw.	3	—
Decaspermum fruticosum Forst.	—	3
Dendrobium guamense Ames	—	9
Desmanthus virgatus (L.) Willd.	8	—
Desmodium umbellatum (L.) DC.	10	—
Dichanthium bladhii (Retz.) Clayton	—	75
Dicranopteris linearis (Burm.) Underwood	—	19
Digitaria bicornis (Lam.) Roemer & J.A. Schultes ex Loud.	10	28
Digitaria ciliaris (Retz.) Koel.	30	—
Dimeria chloridiformis (Gaud.) K. Schum. & Lauterb.	—	36
Discocalyx megacarpa Merrill	—	5
Elephantopus mollis Kunth	—	6
Eleusine indica (L.) Gaertn.	36	5
Entada phaseoloides (L.) Merr.	5	22

Table 11—Average nontree understory cover[a] on FIA field subplots by species and forest type (continued)

Species	Forest type	
	Limestone	Volcanic
	Percent	
Entada pursaetha DC.	12	—
Epipremnum pinnatum (L.) Engl.	27	—
Eragrostis tenella (L.) Beauv. ex Roemer & J.A. Schultes	60	—
Euphorbia chamaesyce L.	10	—
Eustachys petraea (Sw.) Desv.	—	8
Fimbristylis dichotoma (L.) Vahl	8	—
Fimbristylis sp. Vahl	—	10
Flagellaria indica L.	28	14
Flemingia strobilifera (L.) Ait. & Ait. f.	36	—
Freycinetia reineckei Warb.	—	15
Gleichenia linearis (Burm.) Clarke	—	16
Glochidion mariana Mueller-Arg., L.	—	3
Gossypium hirsutum L.	5	—
Grasses	—	10
Heterogonium pinnatum (Copel.) Holtt.	—	3
Humata heterophylla (Sm.) Desv.	—	5
Hyptis capitata Jacq.	—	9
Hyptis pectinata (L.) Poit.	—	15
Hyptis rhomboidea Mart. & Galeotti	—	5
Ipomoea indica (Burm. f.) Merr.	13	5
Ipomoea littoralis Blume	5	3
Ipomoea obscura (L.) Ker-Gawl.	3	—
Ipomoea triloba L.	7	3
Jasminum marianum DC.	10	25
Lepturus repens (G. Forst.) R. Br.	75	—
Lycopodium cernuum L.	—	7
Lygodium microphyllum (Cav.) R. Br.	10	11
Macroptilium lathyroides (L.) Urban	3	—
Mariscus javanicus (Houtt.) Merr. & Metcalfe	—	70
Maytenus thompsonii Fosb.	5	—
Medinilla sp. Gaud	—	8
Melastoma malabathricum L.	—	4
Merremia peltata (L.) Merr.	7	—
Microlepia speluncae (L.) T. Moore	—	8
Mikania micrantha Kunth	7	18
Mikania scandens (L.) Willd.	9	—
Mimosa pudica L.	9	3
Miscanthus floridulus (Labill.) Warb. ex K. Schum. & Laut.	22	47
Momordica charantia L.	11	70
Myrtella bennigseniana (Volk.) Diels	—	3
Nephrolepis biserrata (Sw.) Schott	10	12
Nephrolepis hirsutula (J.R. Forst.) K. Presl	7	8
Ochrosia mariannensis A. DC.	7	—
Oplismenus compositus (L.) Beauv.	14	20
Oplismenus sp. Beauv.	—	23
Panicum maximum Jacq.	34	—
Paspalum conjugatum Berg.	10	—

Table 11—Average nontree understory cover[a] on FIA field subplots by species and forest type (continued)

Species	Forest type	
	Limestone	Volcanic
	Percent	
Paspalum longifolium Roxb.	3	7
Passiflora foetida L.	11	6
Passiflora suberosa L.	8	—
Pennisetum polystachyon (L.) J.A. Schultes	17	27
Pennisetum purpureum Schumacher	39	10
Phragmites karka (Retz.) Trin ex Steud.	—	44
Phyllanthus saffordii Merrill	—	3
Phymatosorus scolopendria (Burm. f.) Pic. Serm.	7	—
Pilea microphylla (L.) Liebm.	19	—
Piper guahamense DC.	10	3
Pluchea carolinensis (Jacq.) G. Don	—	3
Polygonum minus Huds.	—	25
Polypodium punctatum (L.) Sw.	5	5
Polypodium scolopendria Burm. f.	19	13
Premna serratifolia L.	—	3
Pteris ensiformis Burm. f.	—	50
Pteris quadriaurita Retz.	—	8
Pteris tripartita Sw.	3	—
Pycreus polystachyos (Rottb.) Beauv.	—	15
Pyrrosia lanceolata (L.) Farw.	9	6
Pyrrosia sp. Mirbel	—	7
Rhynchospora rubra Domin	—	13
Saccharum spontaneum L.	—	28
Scaevola frutescens (Miller) Krause	—	3
Scleria polycarpa Boeck.	15	11
Senna alat (L.) Roxb.	6	—
Unknown shrub	10	—
Solanum americanum P. Mill.	—	3
Spathoglottis plicata Blume	—	3
Stachytarpheta jamaicensis (L.) Vahl	16	4
Stachytarpheta urticifolia Sims	19	6
Stacytharpheta jamaicensis (L.) Vahl	3	4
Stictocardia tiliaefolia (Desr.) H. Hallier	—	8
Stylosanthes guianensis (Aubl.) Sw.	—	7
Syngonium augustatum Schott	8	—
Thelypteris gretheri (Wagner) Stone	13	—
Thelypteris maemonensis (Wagner & Grether) Stone	3	—
Thelypteris opulenta (Kalfuss) Fosberg	5	10
Thelypteris parasitica (L.) Fosberg	—	9
Thelypteris subpubescens Blume	—	13
Thelypteris unita (L.) C.V. Morton	—	6
Trichomanes brevipes (C. Presl.) Baker	—	5
Waltheria indica L.	17	8
Wikstroemia elliptica Merr.	6	3
Zoysia matrella (L.) Merr.	7	—

[a] The cover estimates are averaged among subplots where each species was found.

Table 12—Average understory tree cover on FIA field subplots by species and forest type

Species	Forest type	
	Limestone	Volcanic
	Percent	
Adenanthera pavonina	3	—
Aglaia mariannensis	4	—
Annona muricata L.	7	3
Annona reticulata	8	—
Areca catechu	—	8
Artocarpus altilis	3	—
Averrhoa bilimbi	5	—
Barringtonia racemosa	—	3
Bauhinia monandra	—	10
Calophyllum inophyllum	—	4
Cananga odorata	3	—
Carica papaya	3	—
Casuarina equisetifolia	—	3
Cerbera dilatata	4	—
Cocos nucifera	7	14
Cycas micronesica	8	6
Diospyros kaki L. f.	3	—
Eugenia reinwardtiana	3	—
Ficus prolixa	7	—
Guamia mariannae	11	3
Heterospathe elata	20	10
Hibiscus tiliaceus	7	5
Kleinhovia hospita	8	—
Leucaena leucocephala	11	4
Mangifera indica	—	3
Morinda citrifolia	7	6
Neisosperma oppositifolia	3	—
Pandanus tectorius	5	8
Pipturus argenteus	3	—
Polyscias grandifolia	—	7
Premna obtusifolia	6	—
Psidium guajava	3	4
Triphasia trifolia	11	13
Vitex parviflora	5	10

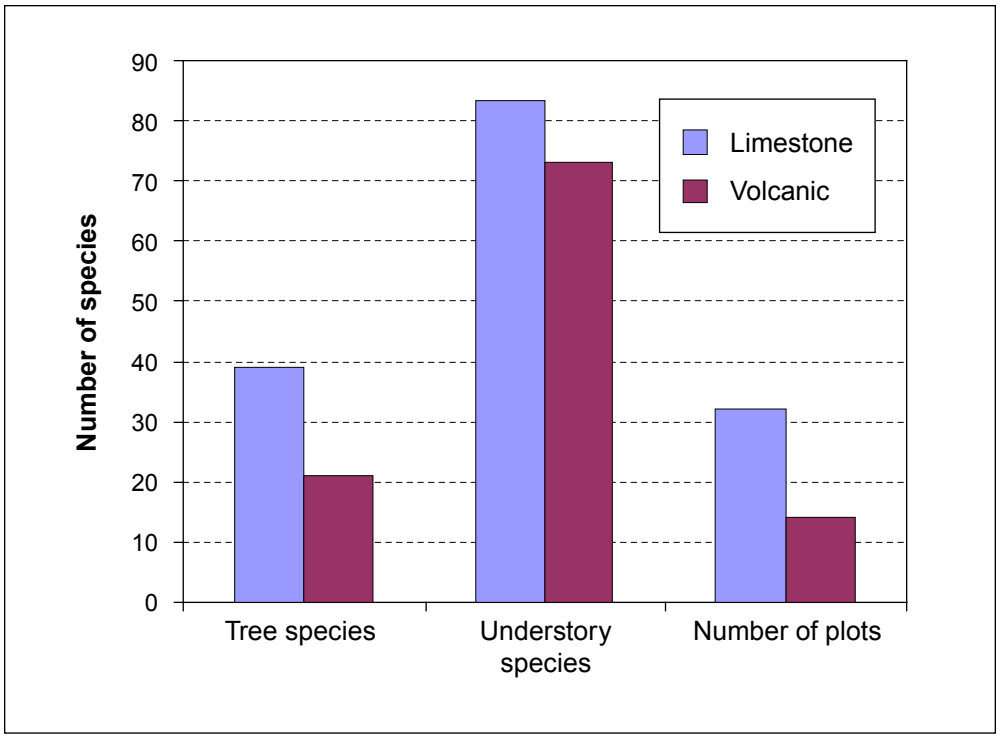

Figure 11—Forty-eight tree species and about 140 understory species were measured on 46 plots in Guam.

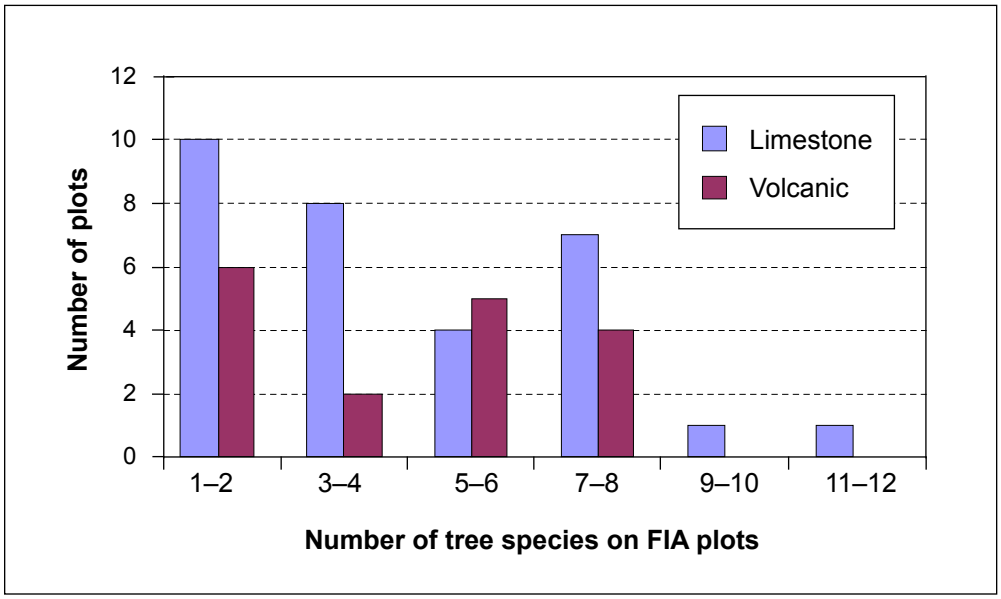

Figure 12—The average number of tree species per sixth-acre plot on both limestone and volcanic soils was four.

Table 13—Number of trees by primary damage type and species for all trees (≥5 inches diameter at breast height; includes dead trees)

Species	No damage	Broken bole	Broken branches	Broken roots	Conks	Damaged shoots	Lost apical dominance	Open wound	Vines in crown	All damages
					Number of trees					
Adenanthera pavonina	14,490	—	28,981	—	14,490	—	—	—	—	43,471
Aglaia mariannensis	275,319	14,490	—	—	14,490	—	—	14,490	—	43,471
Annona reticulata	72,452	—	—	—	14,490	—	—	—	—	14,490
Areca catechu	44,330	—	—	—	—	—	—	—	—	—
Artocarpus altilis	73,311	—	—	—	—	—	43,758	—	—	43,758
Artocarpus mariannensis	14,490	—	—	—	—	—	—	—	—	—
Averrhoa bilimbi	57,962	—	—	—	—	—	—	—	—	—
Barringtonia asiatica	14,490	—	—	—	—	—	—	14,490	—	14,490
Barringtonia racemosa	—	—	—	—	29,553	—	—	—	—	29,553
Calophyllum inophyllum	59,107	—	—	—	—	—	—	—	—	—
Cananga odorata	14,490	—	—	—	—	—	—	—	—	—
Carica papaya	57,962	—	28,981	—	—	—	14,490	—	—	43,471
Casuarina equisetifolia	115,924	—	—	—	—	—	—	—	—	—
Ceiba pentandra	14,490	—	—	—	—	—	—	—	—	—
Cerbera dilatata	144,905	—	—	—	14,490	—	28,981	—	—	43,471
Cocos nucifera	1,074,979	—	—	—	29,553	14,490	—	58,248	—	102,292
Cyathea lunulata	29,553	—	—	—	—	—	—	—	—	—
Cycas micronesica	1,280,888	14,490	43,758	—	115,924	—	—	72,452	87,515	334,140
Eugenia thompsonii	29,553	—	—	—	—	—	—	—	—	—
Ficus prolixa	131,273	—	—	—	—	—	14,490	—	—	14,490
Ficus tinctoria	14,490	—	—	—	—	—	14,490	—	—	14,490
Guamia mariannae	86,943	—	—	—	—	14,490	14,490	14,490	—	43,471
Hernandia ovigera	115,924	—	14,490	—	—	—	—	—	—	14,490
Hernandia sonora	—	—	—	—	28,981	—	—	—	—	28,981
Heterospathe elata	1,045,998	—	—	—	—	—	—	29,553	—	29,553
Hibiscus tiliaceus	219,933	—	101,433	—	159,682	101,433	14,777	14,490	—	391,816
Intsia bijuga	57,962	—	—	—	14,490	—	—	—	—	14,490
Kleinhovia hospita	57,962	—	—	—	—	—	—	—	—	—
Leucaena leucocephala	772,576	—	—	—	58,534	—	14,777	44,330	—	117,641
Macaranga thompsonii	144,905	—	—	—	14,490	—	14,490	14,490	—	43,471
Mangifera indica	177,321	14,777	—	—	14,777	—	29,553	29,553	—	88,660
Morinda citrifolia	29,267	—	29,553	—	—	—	—	—	—	29,553
Neisosperma oppositifolia	14,490	—	—	—	—	—	—	—	—	—
Pandanus tectorius	688,781	58,248	29,267	—	—	—	—	—	44,330	131,846
Premna obtusifolia	376,753	14,490	—	43,471	130,414	—	14,490	14,490	57,962	275,319
Spathodea campanulata	57,962	—	—	—	—	—	—	—	—	—
Vitex parviflora	743,022	29,267	58,248	—	28,981	—	57,962	14,490	—	188,949
Xylosma nelsonii	14,490	—	—	—	—	—	—	—	—	—
Total	8,138,752	145,764	334,712	43,471	683,343	130,414	276,750	335,571	189,808	2,139,834

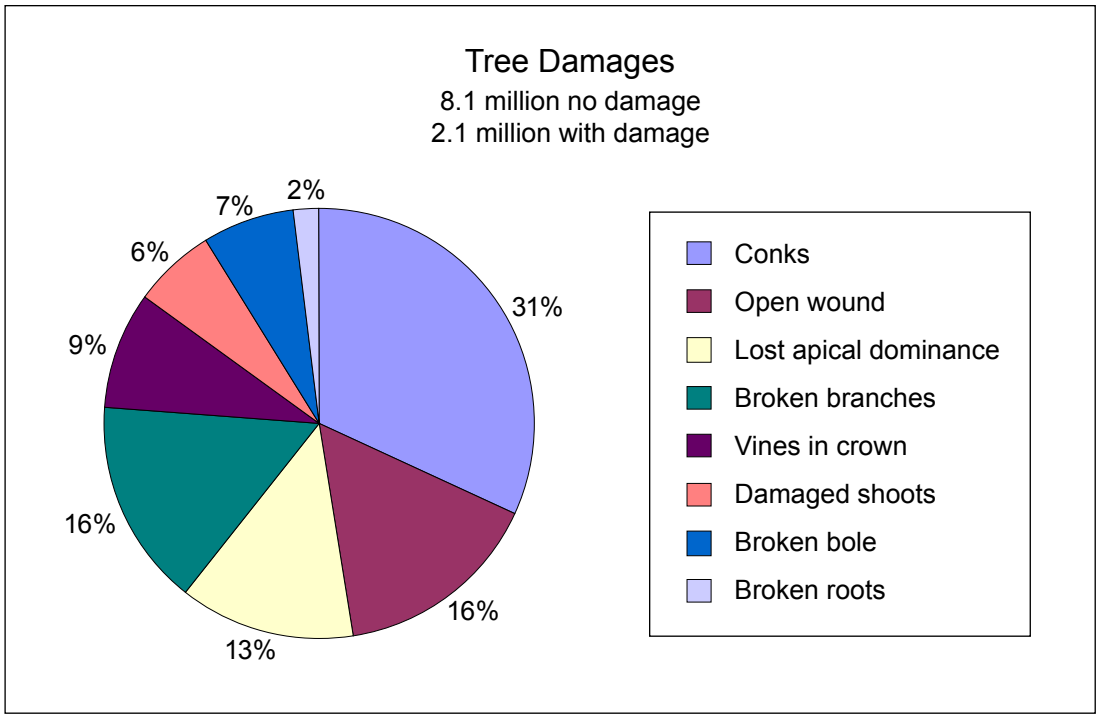

Figure 13—Broken boles, branches, and roots accounted for 25 percent of the damages on Guam. An additional 31 percent of the damages were due to rot evidenced by shelf-fungus conks.

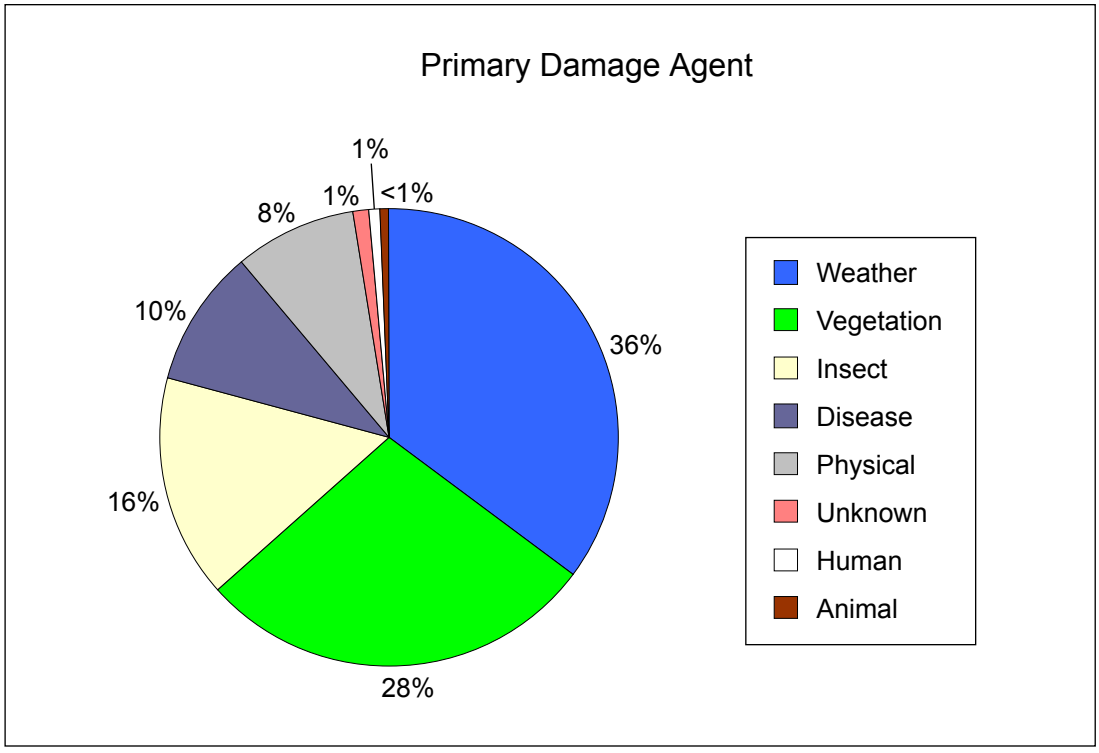

Figure 14—Weather and mechanical impacts by other vegetation accounted for 64 percent of the primary damages.

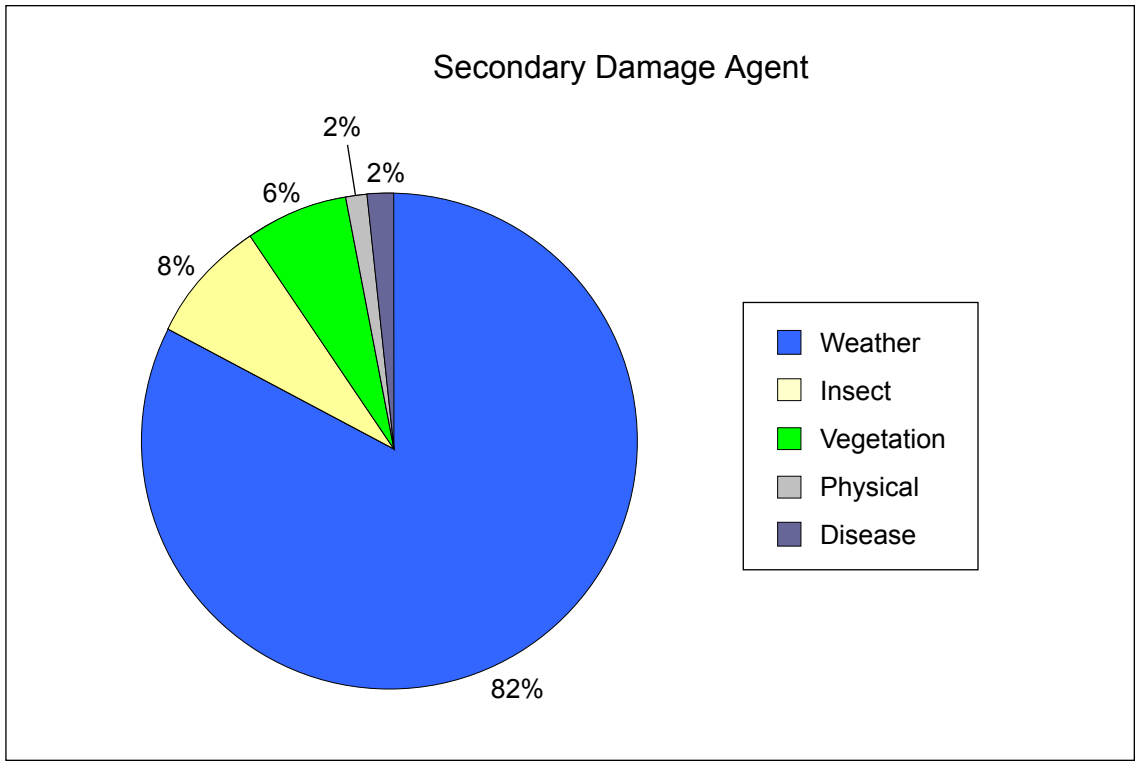

Figure 15—Secondary damage was generally attributed to weather.

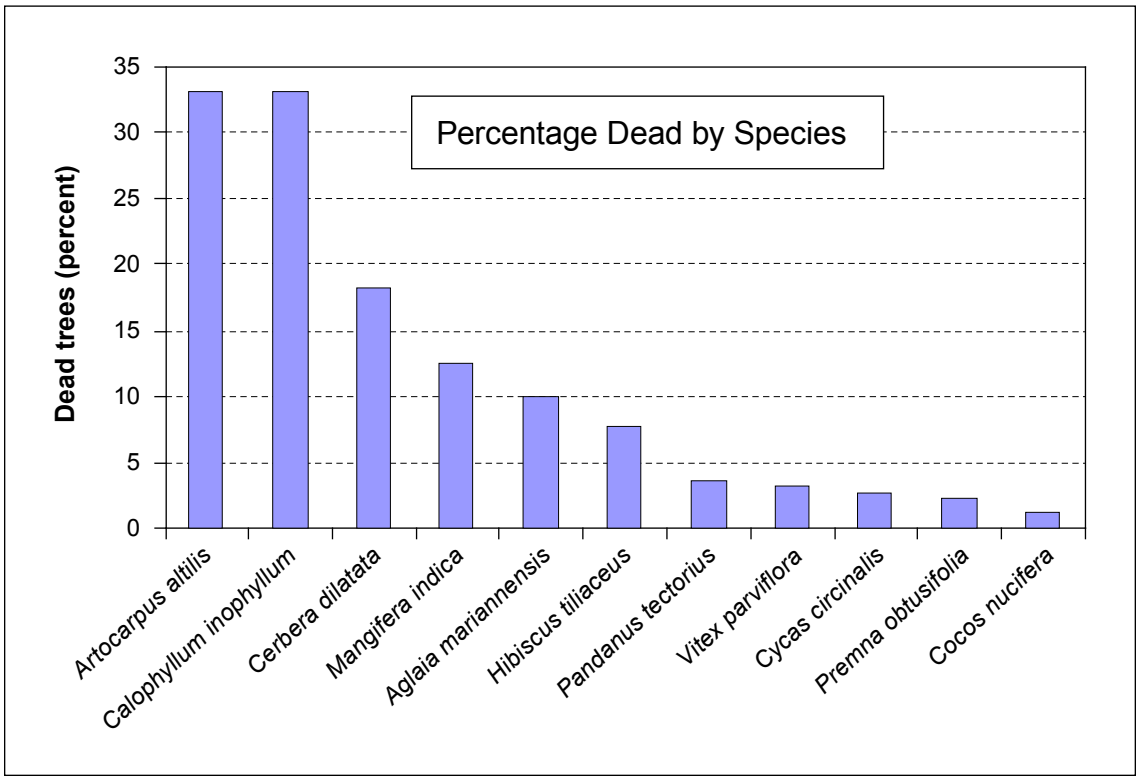

Figure 16—Soft-wooded species, such as *Artocarpus altilis*, tended to suffer high mortality.

Epiphytes

Epiphytic plants growing on trees use space and moisture that might otherwise be available for the growth of the host tree. Physical breakage of tree limbs can occur depending on the amount and species of plants growing in the branching network of the host tree. In extremely wet areas, the weight loading of epiphytes can be tremendous, stunting the growth of individual trees. We rated each tree sampled in the inventory according to epiphyte loading. The majority of trees on Guam show little evidence of epiphyte loading (table 14). Frequent storm damage to trees may prevent the accumulation of epiphytes to the point of tree limb damage on Guam.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	.3048	Meters
Miles	1.609	Kilometers
Acres	.405	Hectares
Cubic feet	.0283	Cubic meters
Tons	907	Kilograms
Tons per acre	2.24	Tonnes or megagrams per hectare
Cubic feet per acre	.06997	Cubic meters per hectare
Trees per acre	2.471	Trees per hectare

Table 14—Estimated number of trees on forest land by epiphyte loading (amounts of nontree vegetation in the canopy and branches) and species (includes dead trees)

Species	Epiphyte loadings				All loadings
	None	Low	Moderate	High	
			Number of trees		
Adenanthera pavonina	28,981	—	28,981	—	57,962
Aglaia mariannensis	217,357	72,452	28,981	—	318,791
Annona reticulata	43,471	28,981	14,490	—	86,943
Areca catechu	44,330	—	—	—	44,330
Artocarpus altilis	58,248	—	44,044	14,777	117,069
Artocarpus mariannensis	—	14,490	—	—	14,490
Averrhoa bilimbi	14,490	43,471	—	—	57,962
Barringtonia asiatica	14,490	14,490	—	—	28,981
Barringtonia racemosa	14,777	14,777	—	—	29,553
Calophyllum inophyllum	44,330	—	14,777	—	59,107
Cananga odorata	14,490	—	—	—	14,490
Carica papaya	101,433	—	—	—	101,433
Casuarina equisetifolia	—	115,924	—	—	115,924
Ceiba pentandra	14,490	—	—	—	14,490
Cerbera dilatata	101,433	72,452	—	14,490	188,376
Cocos nucifera	499,832	515,181	73,597	88,660	1,177,271
Cyathea lunulata	—	—	—	29,553	29,553
Cycas micronesica	565,415	596,686	379,043	73,884	1,615,028
Eugenia thompsonii	—	29,553	—	—	29,553
Ficus prolixa	73,311	28,981	43,471	—	145,764
Ficus tinctoria	28,981	—	—	—	28,981
Guamia mariannae	86,943	43,471	—	—	130,414
Hernandia ovigera	—	86,943	43,471	—	130,414
Hernandia sonora	14,490	14,490	—	—	28,981
Heterospathe elata	883,454	177,321	14,777	—	1,075,552
Hibiscus tiliaceus	450,923	160,827	—	—	611,749
Intsia bijuga	14,490	57,962	—	—	72,452
Kleinhovia hospita	57,962	—	—	—	57,962
Leucaena leucocephala	247,769	350,920	277,037	14,490	890,217
Macaranga thompsonii	144,905	14,490	28,981	—	188,376
Mangifera indica	73,884	162,544	14,777	14,777	265,981
Morinda citrifolia	58,821	—	—	—	58,821
Neisosperma oppositifolia	—	14,490	—	—	14,490
Pandanus tectorius	351,493	248,628	176,176	44,330	820,627
Premna obtusifolia	202,867	202,867	202,867	43,471	652,072
Spathodea campanulata	28,981	28,981	—	—	57,962
Vitex parviflora	566,560	306,876	28,981	29,553	931,971
Xylosma nelsonii	14,490	—	—	—	14,490
Total	5,077,896	3,418,252	1,414,451	367,987	10,278,586

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