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Commonwealth of the Northern Mariana Island's Forest Resources: Forest Inventory and Analysis, 2015

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Cover photo: Southern Tinian viewed from Carolinas Limestone Forest Trail. USDA Forest Service photo by Ashley D. Lehman.

Abstract

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In 2015, the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis program collected forest and tree measurements from 37 plots among three forest communities on the islands of Rota, Saipan, and Tinian in the Commonwealth of the Northern Mariana Islands (CNMI). A total of 36 tree species and 132 dominant vascular plant species were recorded, including 28 invasive species. Invasive plant species covered most of the forest area, and 9 of the top 20 most dominant nontree plant species were invasive. The small tree *Leucaena leucocephala* (tångantångan), comprising by far the largest invasive component in CNMI, made up a substantial percentage of damaged trees and was the only tree species removed by people between inventories (2004–2015). Tree damages from coconut rhinoceros beetles and forest disturbance from wild pigs were not observed.

Rota had the least disturbed forests among inventoried islands, with the most native forest—about two-thirds of the total forest area was undisturbed. About 60 percent of the forest area on Saipan and 100 percent of the forest area on Tinian were disturbed. Tree disease was the most prevalent disturbance and damage type in 2015. Vegetation suppression due to vines occurred in about one-third of the total forest area. Disturbance from livestock affected about 10 percent of the total forest area (mostly on Tinian). This was roughly the same situation as in the 2004 inventory. In both inventories, tree stem density was about 1,400 stems per acre, and forests were dominated by small trees less than 3 inches in diameter at breast height (DBH). About 11 percent of these trees grew into the 3.0–4.9-inch DBH size class between inventories, and although the mean DBH, tree height, and stem density did not change significantly between 2004 and 2015 in CNMI forests, there was a significant increase in mean basal area per acre.

KEYWORDS:

Carbon
Chamorro
Commonwealth of the Northern Mariana Islands
Inventory
Micronesia

Highlighted Forest Inventory and Analysis Statistics, Commonwealth of the Northern Mariana Islands

- Estimated total forest area: 60,207 acres
- Estimated total number of live trees ≥1-inch diameter at breast height: 83,813,945
- Estimated total live, aboveground biomass: 1,617,573 tons
- Estimated total live, aboveground tree carbon: 761,283 tons

Preface

U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) is one of the largest ground-based forest monitoring programs in the world, continuously measuring forest structure and health across 49 of the United States and collecting forest data in Hawai'i, U.S. territories, and the U.S.-Affiliated Pacific Islands about every 10 years. The FIA program began working with the U.S.-Affiliated Pacific Islands and other U.S. territories in 2001. The first forest inventory in the Commonwealth of the Northern Mariana Islands began in 2004, and these plots were remeasured in 2015 (Agricultural Act 2014).

Differences Between 2004 and 2015 Inventories and Reports

There were some differences in the methodology protocol between the 2004 and 2015 inventories, and differences in reporting of summary results. Live canopy cover for the entire plot, pig damage of subplot area, and percentage of invasive species cover were not measured in the 2004 inventory, and percentage of forest area by disturbance, dominant species, growth habit, and canopy layer were not mentioned in the 2004 report.

The topographic relative moisture index of forests in the Commonwealth of the Northern Mariana Islands was not recalculated for the 2015 report.

Number of subplots, mean cover, and standard deviation for understory species and tree seedlings were listed for all species in the 2004 report, but only the top 20 most common understory and tree seedling/sapling species are listed by percentage of forest area covered in the 2015 report.

Contents

Introduction

This summary of forest resources for the three major islands—Rota, Saipan, and Tinian—of the Commonwealth of the Northern Mariana Islands (CNMI) is based on forest inventories conducted in 2004 and 2015 by the U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis (FIA) program in partnership with the CNMI Department of Lands and Natural Resources, Division of Agriculture, Forestry Program. Guam, about 50 miles south of Rota, is geographically one of the Mariana Islands; however, it is politically administered as a separate territory of the United States, so its inventory results are released in a separate, stand-alone report. The inventory was designed to monitor the status and trends of forested ecosystems, provide information that forest resource managers need for informed decision making, and share forestry skills among jurisdictions and agencies. The forest resources in the CNMI are described in detail in the national forest action plan (CNMI SWARS 2015). The plan includes descriptions of forests and their ecosystem services on Rota, Saipan, and Tinian. It also describes high-priority landscapes and the primary threats to the health of trees, forests, and terrestrial wildlife in the CNMI.

Geography and Climate of the CNMI

The CNMI is an archipelago in the northwestern Pacific Ocean about 1,000 miles south of Japan. The entire chain of 14 islands stretches for more than 400 miles. The sampled areas reported in this inventory of the CNMI cover 64.2 percent of the total land area. Rota, Saipan, and Tinian are the three largest, oldest, and southernmost islands (excluding Aguijan) in the commonwealth (figs. 1–3). Nearly the entire population of 47,329 resides on these three islands (U.S. Census Bureau 2022). Saipan, with a population of 43,385, is the commercial center and capitol of the commonwealth. The two main ethnic communities in CNMI are the Chamorros and the Carolinians. Both communities have a cultural connection to the forest and consider several of its species to be traditionally important (Demeulenaere et al. 2020, Nandwani et al. 2008).

The CNMI has a hot and humid tropical climate yearround (NCEI 2020a, b). Mean minimum and maximum

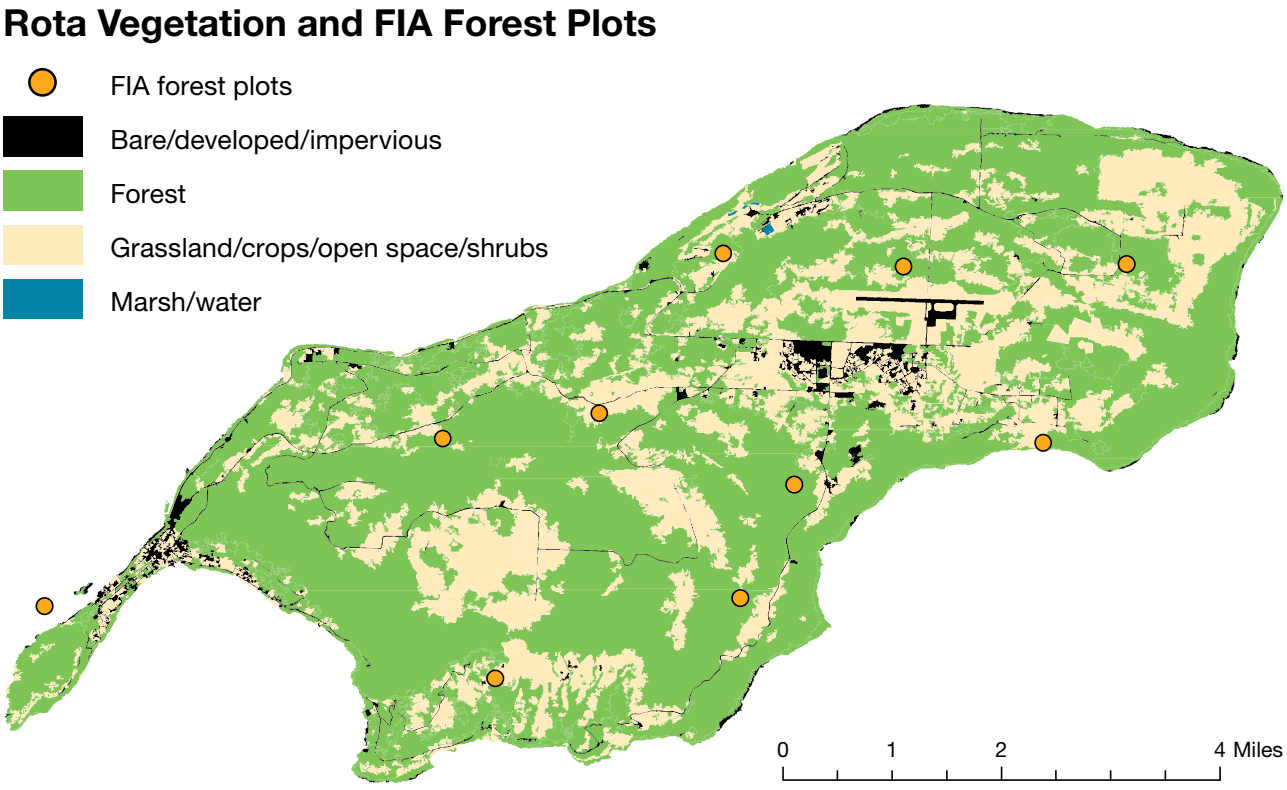

Figure 1—The island of Rota, Commonwealth of the Northern Mariana Islands, vegetation cover (USDA FS 2006) and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots. Plot locations are approximate.

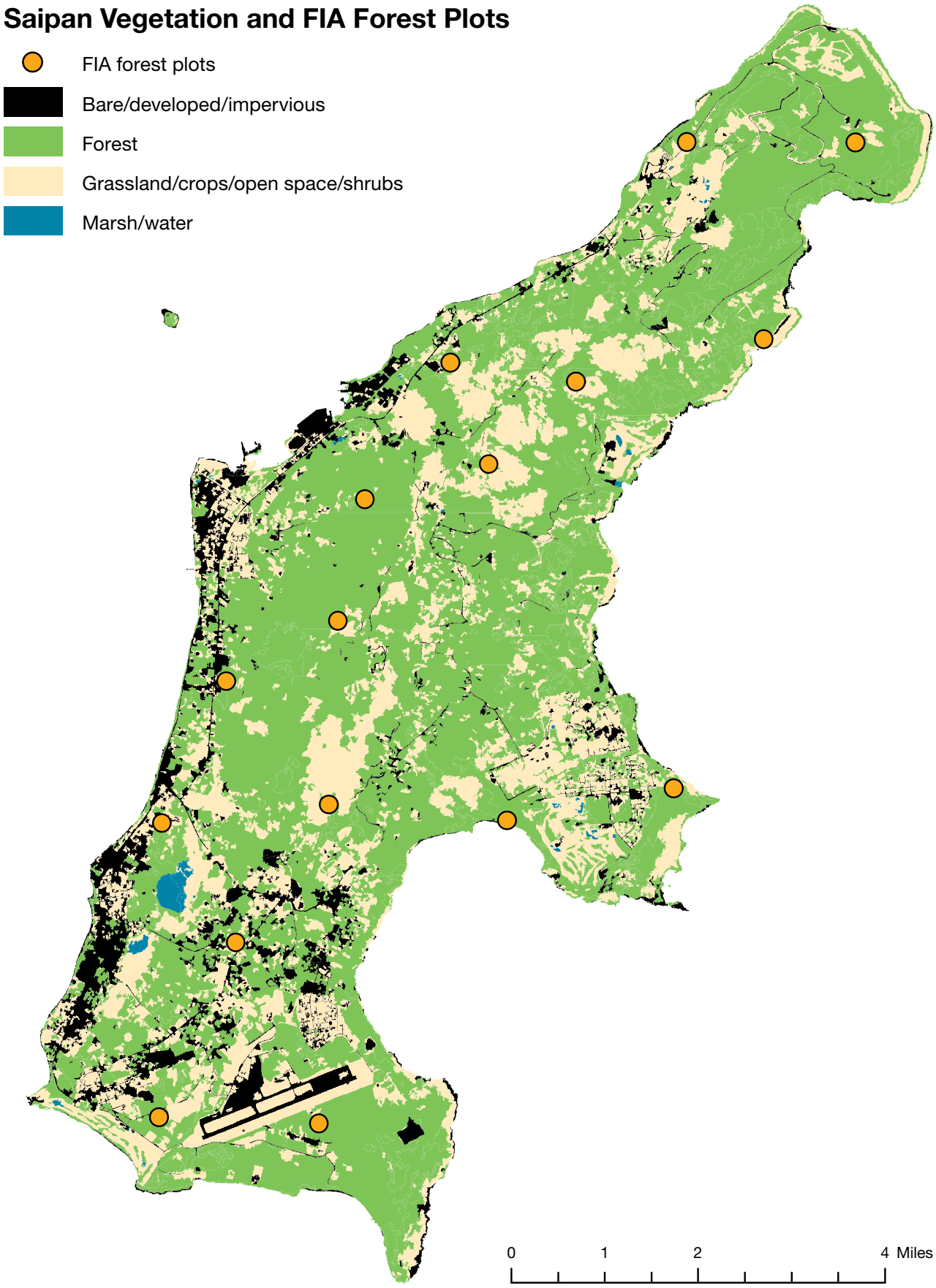

Figure 2—The island of Saipan, Commonwealth of the Northern Mariana Islands, vegetation cover (USDA FS 2006) and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots. Plot locations are approximate.

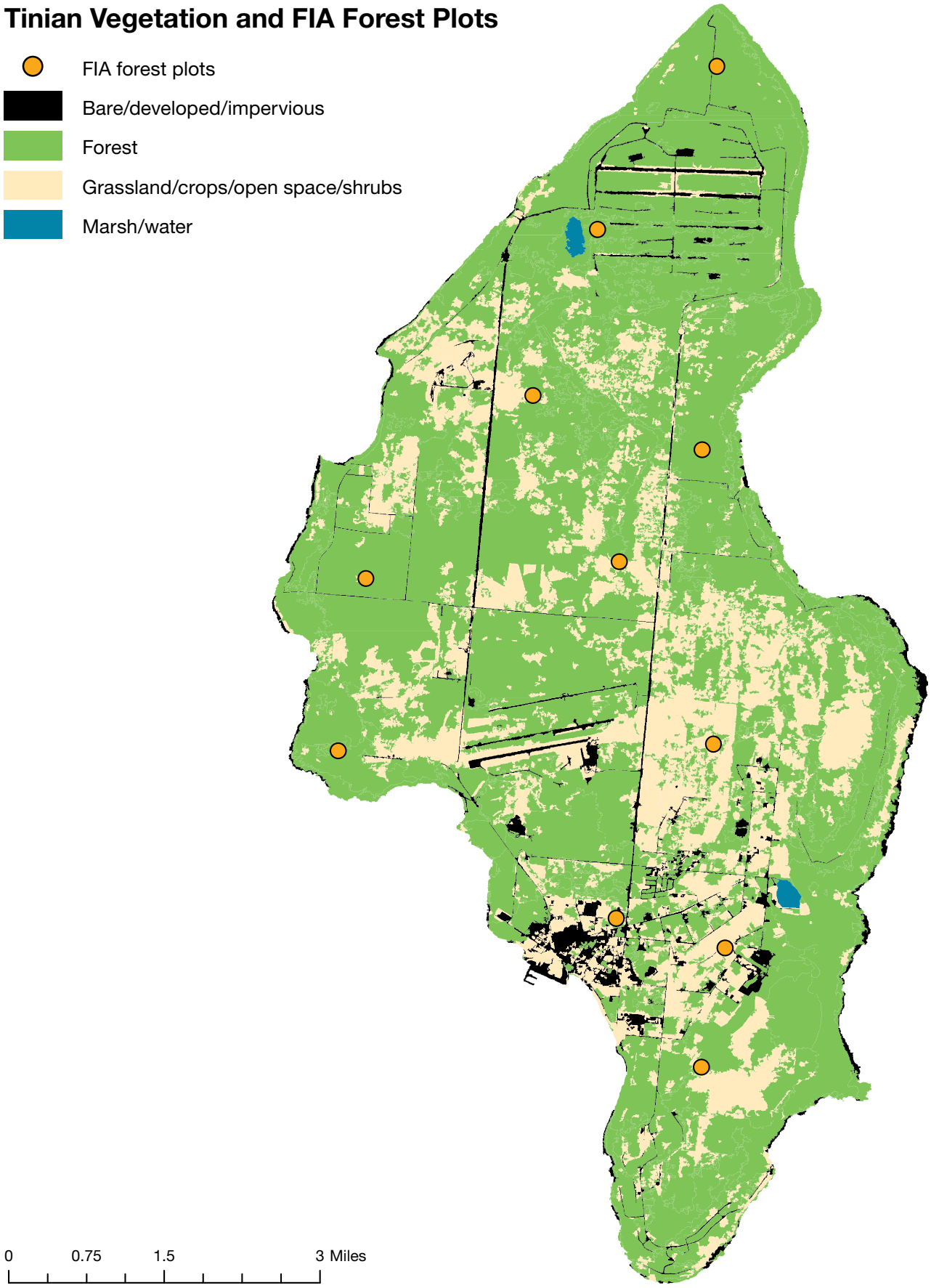

Figure 3—The island of Tinian, Commonwealth of the Northern Mariana Islands, vegetation cover (USDA FS 2006) and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots. Plot locations are approximate.

temperatures on Saipan are 76.9 and 86.8 °F, respectively, and vary annually by less than 4 °F (fig. 4) (NCEI 2020b). On Rota, mean minimum and maximum temperatures are 75.0 and 85.5 °F, respectively, with an annual variation of less than 3 °F (NCEI 2020a). Annual precipitation varies more, with a dry season extending from December to June. On Saipan, monthly rainfall may be reduced by 60 percent during the dry season (fig. 5) (NCEI 2020b). Mean rainfall is higher on Rota than on Saipan, with an annual average of 80.5 inches compared to 70.1 on Saipan (NCEI 2020a, b). Weather data was not available for Tinian Island.

The CNMI is located within the typhoon belt of the Northwest Pacific Basin, which is one of the most active typhoon regions on Earth (fig. 6) (Knapp et al. 2010, 2018). Typhoons pass through the Mariana archipelago on average once per year. Significant typhoons in the recent past occurred in 1976 (Typhoon Pamela), 1984 (Typhoon Ike), 1988 (Typhoon Roy), 1997 (Typhoons Keith, Joan, Ivan, Paka, and Winnie), 2002 (Typhoons Higos and Pongsona), 2004 (Typhoons Chaba and Tingting), 2005 (Typhoon Nabi), 2007 (Typhoon Kong-rey), 2009 (Typhoon Choi-wan), 2011 (Typhoon Ma-on), 2013 (Typhoon Lekima), and 2015 (Typhoons Chan-hom, Dolphin, Koppu, and Soudelor). In 2018, Typhoon Mangkhut hit Rota, and Typhoon Yutu struck Saipan and Tinian. The effects of these two typhoons are not described in this report as they took place after the 2015 inventory.

The islands of Rota, Saipan, and Tinian are mostly covered by limestone terraces and outcrops over ancient volcanic cores, with small patches of volcanic soils on the surface, especially Saipan (USDA SCS 1989). Most of the CNMI exhibits internal drainage with little to no

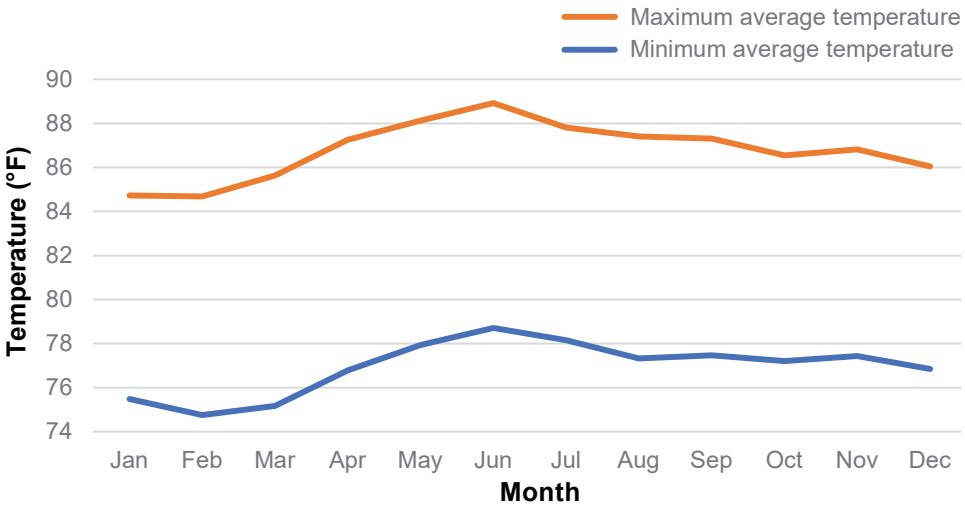

Figure 4—Daily average maximum and minimum temperatures at Saipan International Airport by month from January 1995 to December 2019 (NCEI 2020b).

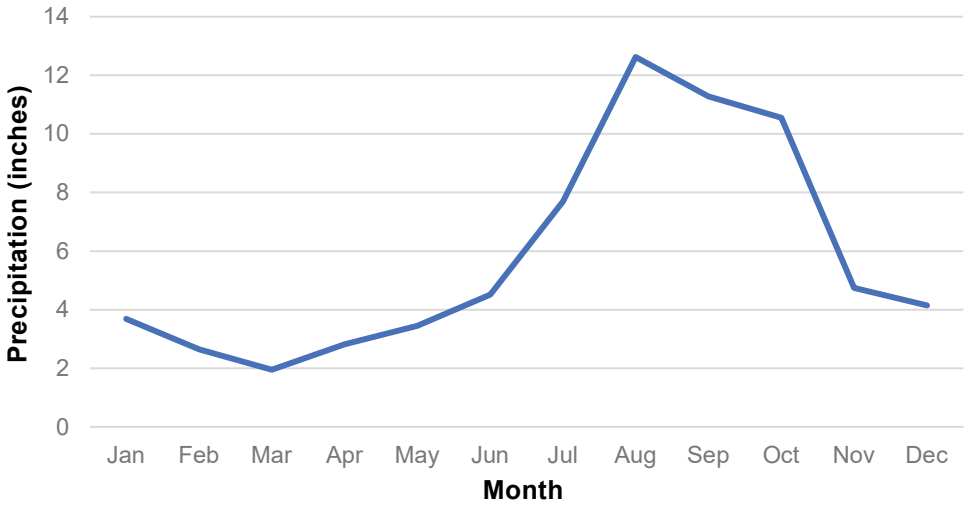

Figure 5—Average monthly precipitation at Saipan International Airport from January 1995 to December 2019 (NCEI 2020b).

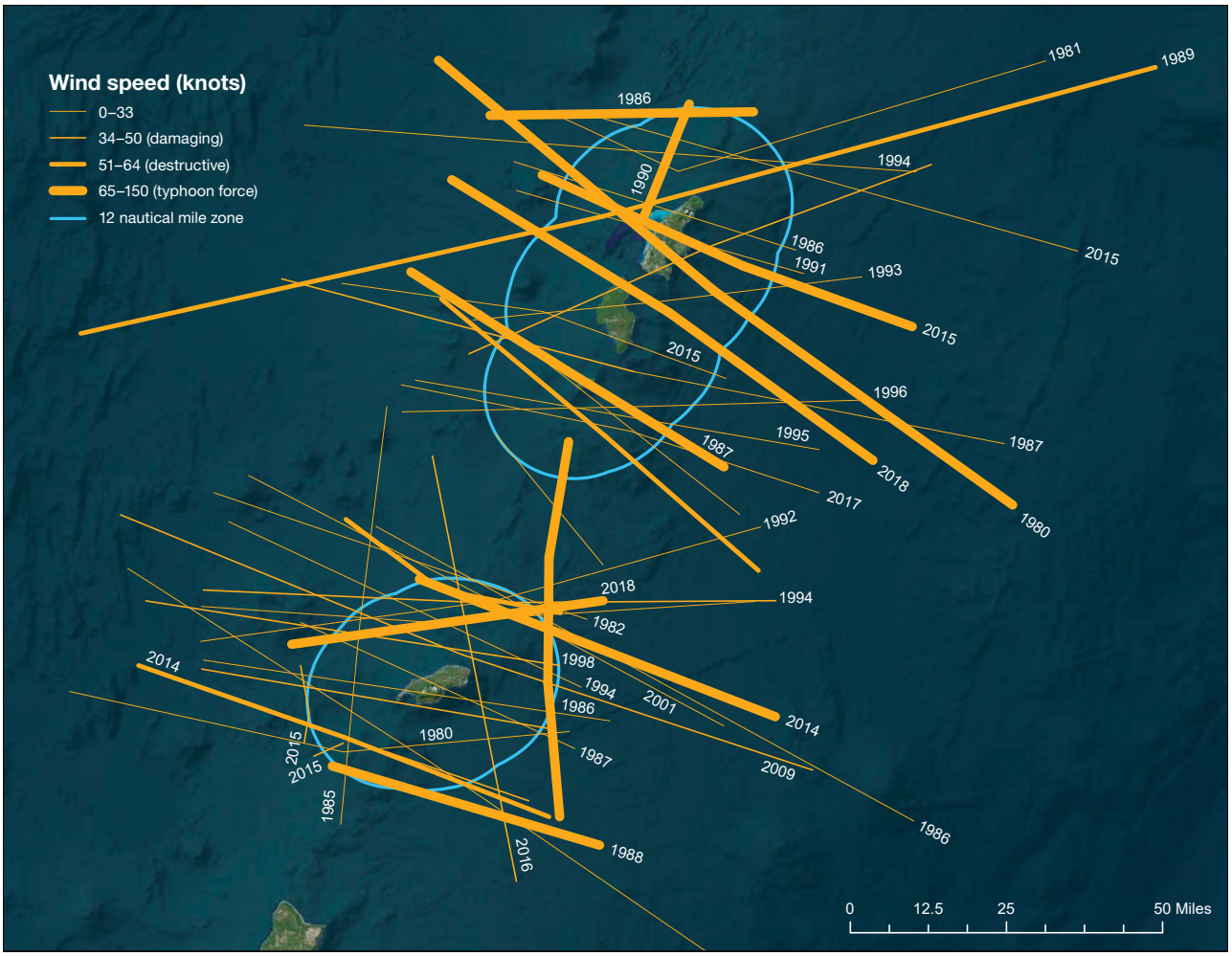

Figure 6—Typhoon tracks (1980–2021) intersecting the 12 nautical mile zone of the Commonwealth of the Northern Mariana Islands (Knapp et al. 2010, 2018).

surface water present. Saipan and Rota have small areas of exposed volcanic soils with streams and complicated drainage patterns (Mueller-Dombois and Fosberg 1998).

Soils in the CNMI are divided into three general categories pertaining to forest cover: lowlands, limestone plateaus, and uplands (USDA SCS 1989). The lowland soil category occurs on very deep and well-drained sandy soils supporting strand forests and constitutes about 2 percent of the soils on Rota and Tinian and 1 percent of the soil on Saipan. Limestone plateau soils compose about 69, 36, and 92 percent of soils on Rota, Saipan, and Tinian, respectively. Upland soils make up about 25, 62, and 5 percent of soils on Rota, Saipan, and Tinian, respectively. Most of the exposed volcanic soils are located within the upland soil category and make up 2, 17, and 1 percent of soil by respective island. The upland soil category also contains steep and rugged limestone escarpments.

Island vegetation has been extensively altered and disturbed by human activities, particularly during the past few centuries of colonial resource extraction and military conflicts. Most flat areas on Saipan and Tinian were cleared by the Imperial Japanese administration for sugar cane production prior to World War II. Nearly all areas with volcanic soils were cleared and burned for agriculture, which, combined with lower rainfall during the dry season, has resulted in secondary savannas (Mueller-Dombois and Fosberg 1998). Most native vegetation and forest are found on steep limestone slopes or cliffs (fig. 7), and much of the little that remained after the war was on Rota. The U.S. administration spread seeds of the tree *Leucaena leucocephala* (tångantångan) to stabilize soils, and this species has dominated the landscape on Saipan and Tinian since the 1950s (Mueller-Dombois and Fosberg 1998).

Figure 7—Limestone forest at I'Chenchon Park Bird Sanctuary on the island of Rota, Commonwealth of the Northern Mariana Islands. USDA Forest Service photo by Seth Ayotte.

Vegetation types that have been mapped in the CNMI include agroforest, agroforest with coconut, barren/sandy beach/bare rocks, *Casuarina* thicket, cropland, *Leucaena leucocephala,* mixed limestone forest, native limestone forest, other shrub and grass, ravine forest, strand, savanna complex, urban vegetation, urban/built-up, water, and wetland (USDA FS 2006). Previous vegetation classes have also included atoll forest, *Casuarina* forest, mangrove forest, introduced trees, secondary vegetation, freshwater marsh, and grassland (Falanruw et al. 1989). Mueller-Dombois and Fosberg (1998) described the main forest types and their general characteristics with common species for Micronesia, including the CNMI. The FIA program adapted those definitions for use as "forest communities" in the region. Strand or halophytic vegetation (strand forest) (fig. 8), lowland tropical rainforest, and agroforest forest communities were inventoried, but the number of sampled plots in strand forest and agroforest were too small to summarize reliably.

Figure 8—Field crew members in a strand forest on southeast Saipan near the Forbidden Island Marine Sanctuary, Commonwealth of the Northern Mariana Islands. USDA Forest Service photo by Seth Ayotte.

Forest Inventory and Analysis Program

The plot sampling intensity was increased by a factor of three in the CNMI, with plots being sampled every 2,000 acres rather than every 6,000 acres, as in the contiguous U.S. inventory. This intensification better accounts for high diversity on a small land mass and provides a statistically relevant sample.

The FIA plot cluster covers an area of about 1.5 acres and is composed of four 24-foot fixed radius subplots, with three subplots equidistant from a central subplot like spokes on a wheel (fig. 9). Field crews assigned condition classes and their proportions to the accessible forest land area sampled by each plot. The forest condition characteristics measured on accessible forest land and estimated for each condition on the entire plot footprint included forest disturbances, forest community, and dominant tree species. Live and dead trees that were 5 inches diameter at breast height (DBH) or greater were measured in the subplots, with a cumulative area of about ⅙ of an acre or 676 m^2 (0.07 hectares); live and dead trees that were 1.0 to 4.9 inches DBH were measured in the microplots, with a cumulative area of about ⅕₅ of an acre or 53 m^2 (0.005 hectares). In addition to DBH, crews measured tree height, identified tree species, and recorded tree damages from subplots and microplots. Crews estimated species cover on each subplot for the four most dominant species (with at least 3-percent cover) in each different growth habit: trees, shrubs, forbs, and grasses.

The FIA program uses a statistical method called poststratification (based on the number of forest pixels in the satellite image used for each measurement cycle) to generate the estimated totals at the jurisdictional level from the plot-level data. This allows for estimates of total numbers or percentages of trees by species or diameter class, forest area by jurisdiction, or percentage of total forest area by forest community, disturbance, or

canopy cover. Estimates were calculated based on the FIA stratification and estimation procedures (Bechtold and Patterson 2005). Growth, removals, and mortality of trees, and change in forest area over time were calculated using a stratification that links measurements from at least two inventories.

The high species diversity and variability of tropical forests relative to the small land area of Pacific Islands tends to result in high sample error (SE) values for FIA estimates in the region. Therefore, for this report, we mostly include results with SE values smaller than the mean, because mean estimates with equivalent or larger SE values are unreliable (appendix 2). We also use the ratio of SE to the estimate to sort results in order of confidence, with the lowest ratio values indicating the greatest confidence in the estimate.

Estimates for forest area and percentage of forest cover are also available from the USDA Forest Service-led Land Cover Monitoring consortium for the U.S.-Affiliated Islands (USDA FS 2006), which provides maps that summarize all vegetation cover using high-resolution satellite imagery (table 1). We merged vegetation classes to make maps comparable across islands and the broader Micronesian region. We merged all nonmangrove and strand forest types into one forest category equivalent to lowland tropical rainforest; we merged all nonforest vegetation categories into the grassland/crops/open space/shrub category; we merged all urban, built-up, and barren categories into the bare/developed/impervious category; and we merged all freshwater marsh, water, and inland water categories into the marsh/water category.

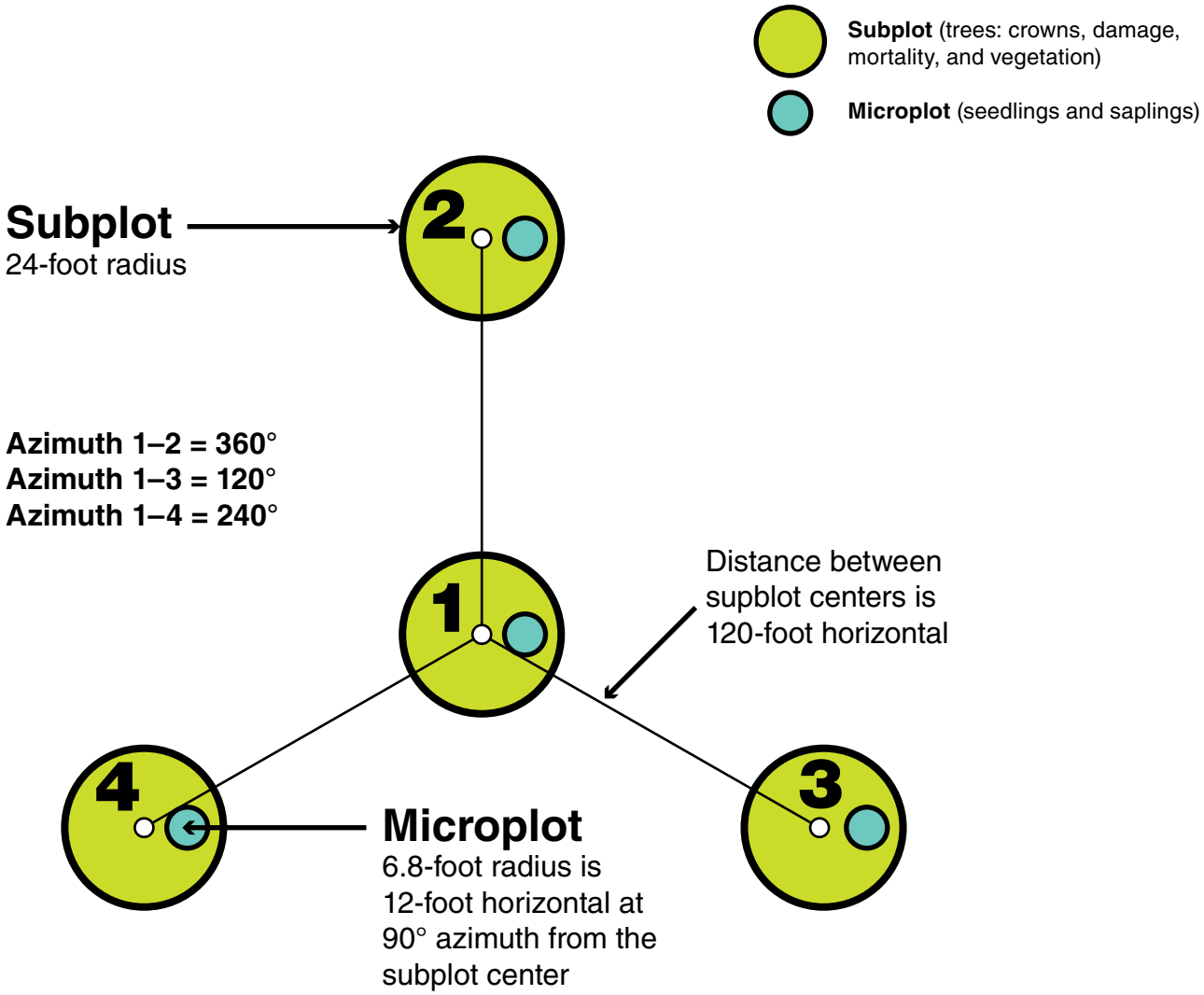

Figure 9—USDA Forest Service Forest Inventory and Analysis plot diagram.

Forest Area and Community

According to CNMI vegetation maps, about 67.9 percent of the land area in the CNMI is forested with similar vegetation cover, but there is much higher urban cover on Saipan (table 1) (USDA FS 2006). Based on the random sampling of forest plots, there were 60,207 acres of forest in the CNMI, of which we estimated that 93 percent (SE = 4) was lowland tropical rainforest, 6 percent (SE = 4) was strand forest, and 1 percent (SE = 1) was agroforest (table 2).

Table 1—Land cover estimates for forest, urban, and nonforest vegetation on Rota, Saipan, and Tinian Islands, Commonwealth of the Northern Mariana Islands

Island	Forest cover	Urban cover	Nonforest vegetation cover
	PERCENT		
Rota	68.4	3.3	28.2
Saipan	64.4	9.4	25.8
Tinian	71.6	4.8	23.6

Source: Most recent available vegetation maps (USDA FS 2006).

Table 2—Forest area (mean and sample error [SE]) by forest community in the Commonwealth of the Northern Mariana Islands

Forest community	Forest area	SE	Total area	SE
	ACRES		PERCENT	
Lowland tropical rainforest	56,019	3,465	93	4
Strand forest	3,766	2,281	6	4
Agroforest	422	462	1	1
Total	**60,207**	**3,030**	**100**	

Live and Missing Canopy Cover

Multiple-layered forest vegetation with high canopy cover maintains understory moisture and temperature, provides a three-dimensional matrix in which diverse life forms carry out their life cycles, and protects erodible soils from intense tropical rains (Mueller-Dombois and Fosberg 1998). The FIA program defines forest as areas that have 10 percent or greater live and missing forest canopy cover (USDA FS 2015). Missing canopy cover estimates are based on canopy cover that existed prior to disturbance or tree harvesting in the past 30 years. In 2015, almost one-third of total forest area in the CNMI and about 40 percent of forest area on Rota and Saipan had 90 percent or greater canopy cover (table 3). Mean canopy cover overall was 71 percent (SE = 3.7). Forest area with missing canopy cover due to human disturbance, including fire, or smothering vegetation, accounted for 7.8 percent (SE = 3.9) of the total and was confined to Saipan and Rota.

Disturbance

Natural and human disturbances to tropical forests affect canopy cover, structure, and plant species diversity and composition, with varied outcomes depending on the disturbance type, duration and intensity, and the timescale afterward (Mueller-Dombois and Fosberg 1998). Forest disturbances, natural or human-caused, must meet some minimum criteria to be recorded. They must be at least 1 acre in size and affect at least 25 percent of all the trees, soil surface, or understory vegetation in the stand. If the disturbance is affecting only one tree species, then 50 percent of this species must be affected to be recorded (USDA FS 2015).

Table 3—Live canopy cover by forest area (mean and sample error [SE]) on Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands (CNMI)

Canopy cover	Rota	SE	Saipan	SE	Tinian	SE	CNMI	SE
PERCENT	PERCENT OF FOREST AREA							
<50	22.0	14.8	16.0	8.2	18.3	12.8	18.4	6.8
50–60	—	—	5.8	4.6	15.5	9.0	7.6	3.8
60–70	3.4	3.4	—	—	15.3	11.5	6.2	4.1
70–80	8.4	8.4	7.9	6.4	10.2	10.2	8.8	5.1
80–90	21.4	15.0	30.3	12.5	30.5	15.5	28.1	8.2
90–100	44.8	19.3	39.9	14.1	10.2	10.2	30.9	8.3

Note: CNMI values represent the islands of Rota, Saipan, and Tinian combined.
— = not observed.

Forests in the CNMI were highly disturbed in 2015, with disturbance recorded on every plot measured on Tinian. Two-thirds of the CNMI forest area was classified as disturbed in 2015, with an overall disturbed forest area of 35.5 percent (SE = 7.8)—almost double that of 2004 (Donnegan et al. 2011). Tree disease was not recorded in 2004, but it was the most prevalent disturbance type by far in 2015, affecting 40.1 percent (SE = 5.4) of forest area in the CNMI and 94.8 percent (SE = 5.0) of forest area on Tinian (table 4). However, the methodology for recording tree disease as an individual tree damage changed between inventories, and the prevalence of stem decay in the abundant tree *Leucaena leucocephala* (tångantångan) resulted in coding tree disease as a disturbance in 2015. Vegetation suppression (vines smothering trees) increased on Rota, Saipan, and Tinian between inventories, from 6.9 (SE = 4.5) to 29.0 percent (SE = 7.7) of total forest area, with almost half of forest area on Tinian affected. Livestock disturbance from cattle was recorded on all three islands and affected more than 10 percent of total forest area in 2015, and disturbance from livestock remained relatively constant across the CNMI between inventories (fig. 10) (Donnegan et al. 2011).

Disturbance from wild pigs was not observed, whereas on the nearby U.S. territory of Guam, wild pigs were a major source of disturbance. The high proportion of limestone substrate in the CNMI may explain this difference.

Wildfires are caused by humans in the CNMI, but disturbance from fire was only recorded on Saipan in the 2015 inventory and was not observed at all in 2004. Satellite-based wildfire monitoring from 2016 to 2023 picked up wildfires on Rota, Saipan, and Tinian, with about 11 percent of total island area burned (1.4 percent per year), but the forest area affected has not been estimated (Earl et al. 2024). Other disturbances attributed to humans were not observed in 2004, but in 2015, general human disturbance affected about 10 percent of forest area on Rota and Saipan (fig. 11). Wind was the only weather disturbance recorded in the CNMI; it occurred on Rota in relation to Typhoon Chaba in 2004.

Figure 10—Cattle pasture and *Leucaena leucocephala* (tångantångan) forests on the island of Tinian, Commonwealth of the Northern Mariana Islands. USDA Forest Service photo by Mikhail Yatskov.

Figure 11—Disturbance after tree cutting on the island of Rota, Commonwealth of the Northern Mariana Islands. USDA Forest Service photo by Matthew O'Driscoll.

Table 4—Forest disturbance by type and forest area (mean and sample error [SE]) on Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands (CNMI)

Distubance type	Rota		Saipan		Tinian		CNMI	
	Area	SE	Area	SE	Area	SE	Area	SE
	PERCENT							
Tree disease	21.4	15.0	4.0	4.0	94.8	5.0	40.1	5.4
Vegetation suppression	10.3	10.3	26.2	12.0	46.4	16.6	29.0	7.7
Animal damage	3.4	3.4	7.8	7.8	20.7	8.7	11.1	5.0
Human	10.8	9.6	9.6	8.6	—	—	6.6	4.2
Insect damage	—	—	7.8	7.8	—	—	3.1	3.1
Weather	11.2	11.2	—	—	—	—	2.9	2.9
Fire	—	—	6.9	6.9	—	—	2.7	2.7
Unknown	—	—	2.0	2.0	—	—	0.8	0.8
Any disturbance	35.7	16.3	60.4	13.3	100.0	0.0	67.7	6.9
Undisturbed	64.3	16.3	39.6	13.3	—	—	32.3	6.9

Note: CNMI values represent the islands of Rota, Saipan, and Tinian combined.
— = not observed.

Trees

Tree Abundance, Dominance, and Species Composition

We used Chamorro common species names for trees compiled by Raulerson and Rinehart (2021) and Falanruw et al. (1990) for the 2015 inventory, which differ from many of the common names currently recorded in the USDA PLANTS database (USDA, n.d.). Chamorro common species names are noted parenthetically following their scientific names at the first mention in each section of this report. Appendix 1 provides a list of scientific names and authorities along with Chamorro or other common names for plants found during the 2015 forest inventory. English and Carolinian common species names for trees can be found in Raulerson and Rinehart (2021).

The most common tree species in the CNMI was the invasive *Leucaena leucocephala* (tångantångan), with about six times the number of live tree stems (≥1-inch DBH) as each of the next four most common species *Pandanus tectorius* (kaffo'), *Maytenus thompsonii* (luluhut), *Cynometra ramiflora* (gulos), and *Guamia mariannae* (paipai) (table 5). *L. leucocephala* also had the highest relative dominance, comprising nearly one-third of the total forest basal area, which was roughly equal to the basal area of the next five most dominant species combined (table 6). It was also dominant across nearly half of the total forest area in the country, or about as much forest area as the next 11 most dominant tree species combined (table 7). *L. leucocephala* has little or no economic value and can form dense thickets that displace native vegetation (UOG and NPS 2018).

We recorded up to three dominant tree species with the largest total canopy cover for each forest condition found on a plot. For 37 total forest plots and 43 conditions in the CNMI, we recorded 19 dominant tree species and were able to reliably estimate forest area covered for 5 of these (table 7). The high number of dominant tree species that we recorded relative to the number of sampled plots and conditions indicates a high diversity of tree species in CNMI forests.

We were able to reliably estimate tree abundance by diameter classes for 32 (70 percent) of the 46 tree species that we identified (table 8). About 57 percent of the tree species we inventoried were <10 inches DBH and 20 percent were measured as saplings <5 inches DBH. The high proportion of species occurring only as saplings or small-diameter trees is a common feature of lowland tropical rainforests with a high diversity of small trees. Eighteen percent (SE = 7) of all observed tree species in the CNMI were endemic to Micronesia, 16 percent (SE = 7) were endemic to the Mariana Islands, and 44 percent (SE = 9) were invasive (CNMI SWARS 2015, Costion and Lorence 2012). There was an average of five tree species per plot (SE = 4.3) among all forest communities, but diversity comparisons among them were not possible due to small plot sample sizes for agroforest and strand forest.

Table 5—Abundance (mean and sample error [SE]) and status of live tree species (≥1-inch DBH) in the Commonwealth of the Northern Mariana Islands

Scientific name	Chamorro common name	All trees	SE	Status
		PERCENT		
Leucaena leucocephala	Tångantångan	42.9	9.1	I*
Pandanus tectorius	Kaffo'	7.7	4.1	N
Maytenus thompsonii	Luluhut	7.5	3.6	C
Cynometra ramiflora	Gulos	7.1	4.1	N
Guamia mariannae	Paipai	6.9	3.0	C
Ficus tinctoria	Hodda	4.2	3.2	N
Annona squamosa	Ates	2.7	2.5	I
Melanolepis multiglandulosa	Ålum	1.9	0.9	N
Premna obtusifolia	Åhgao	1.9	0.6	N
Albizia lebbeck	Trongkon kalaskas	1.6	1.0	I
Hibiscus tiliaceus	Pågo	1.4	0.9	N
Ficus prolixa	Nunu	1.3	0.8	N
Aglaia mariannensis	Mapunyao	1.1	0.5	M
Delonix regia	Atbut	1.0	1.0	I
Psychotria mariana	Aploghating	1.0	0.8	M
Eugenia palumbis	Agatelang	1.0	0.9	C
Pandanus dubius	Påhong	0.9	0.5	N
Eugenia reinwardtiana	A'abang	0.8	0.8	N
Spathodea campanulata	Apär	0.8	0.8	I*

C = endemic to the Mariana Islands, I = introduced, I* = invasive, M = endemic to Micronesia, N = native. DBH = diameter at breast height.

Sources: Chamorro common names: Falanruw et al. (1990), Raulerson and Rinehart (2021); endemism: Costion and Lorence (2012); other status: USDA FS PIER (2018).

Table 6—Twenty most dominant tree species by total basal area (mean and sample error [SE]) of live trees (≥1-inch DBH) in the Commonwealth of the Northern Mariana Islands

Scientific name	Chamorro common name	Total basal area	SE	Status
		PERCENT		
Leucaena leucocephala	Tångantångan	30.8	7.0	I*
Pandanus tectorius	Kaffo'	12.3	6.5	N
Premna obtusifolia	Åhgao	4.6	0.9	N
Cynometra ramiflora	Gulos	4.2	2.4	N
Ficus prolixa	Nunu	4.0	2.3	N
Casuarina equisetifolia	Gågu	3.4	3.1	N
Albizia lebbeck	Trongkon kalaskas	3.2	1.7	I
Ficus tinctoria	Hodda	3.0	1.9	N
Cocos nucifera	Niyog	2.8	2.0	N
Maytenus thompsonii	Luluhut	2.8	1.5	C
Pandanus dubius	Påhong	2.4	1.2	N
Melanolepis multiglandulosa	Ålum	2.3	1.2	N
Guamia mariannae	Paipai	2.3	1.0	C
Hibiscus tiliaceus	Págo	2.1	1.5	N
Hernandia labyrinthica	Oschal	2.0	2.0	N
Intsia bijuga	Ifit	1.8	1.3	N
Artocarpus mariannensis	Dogduk	1.6	1.6	M
Pisonia grandis	Umumu	1.3	1.0	N
Adenanthera pavonina	Kulalis	1.1	1.1	I*
Annona squamosa	Ates	1.1	1.1	I

C = endemic to the Mariana Islands, I = introduced, I* = invasive, M = endemic to Micronesia, N = native. DBH = diameter at breast height.

Sources: Chamorro common names: Falanruw et al. (1990), Raulerson and Rinehart (2021); endemism: Costion and Lorence (2012); other status: USDA FS PIER (2018).

Table 7—Dominant tree species by forest area (mean and sample error [SE]), based on aerial cover, in the Commonwealth of the Northern Mariana Islands

Scientific name	Chamorro common name	Forest area	SE	Status
		PERCENT		
Leucaena leucocephala	Tångantångan	46.8	6.8	I*
Pandanus tectorius	Kaffo'	8.8	4.9	N
Cocos nucifera	Niyog	5.7	3.9	N
Intsia bijuga	Ifit	5.6	4.3	N
Pandanus dubius	Påhong	5.1	3.9	N
Cynometra ramiflora	Gulos	3.5	3.5	N
Pisonia grandis	Umumu	3.1	3.1	N
Spathodea campanulata	Apär	3.1	3.1	I*
Ficus tinctoria	Hodda	2.8	2.8	N
Scaevola taccada	Nanåso	2.8	2.8	N
Acacia confusa	Sosugi	2.7	2.7	I*
Pemphis acidula	Nigas	2.7	2.7	N
Albizia lebbeck	Trongkon kalaskas	2.3	2.3	I
Delonix regia	Atbut	1.5	1.5	I
Ochrosia mariannensis	Langiti	0.9	0.9	C
Hibiscus tiliaceous	Págo	1.0	0.9	N
Artocarpus altilis	Lemai	0.8	0.8	I
Premna obtusifolia	Åhgao	0.7	0.7	N

C = endemic to the Mariana Islands, I = introduced, I* = invasive, M = endemic to Micronesia, N = native.

Sources: Chamorro common names: Falanruw et al. (1990), Raulerson and Rinehart (2021); endemism: Costion and Lorence (2012); other status: USDA FS PIER (2018).

Table 8—Number of live trees on forest land by species and diameter class in the Commonwealth of the Northern Mariana Islands

Scientific name (Chamorro common name)	1.0–4.9 inch diameter class		5.0–10.0 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
	NUMBER OF TREES							
Leucaena leucocephala (tångantångan)	35,058,848	8,506,940	872,014	197,129	—	—	35,930,862	8,598,023
Pandanus tectorius (kaffo')	5,554,637	2,835,965	896,845	749,251	—	—	6,451,482	3,431,368
Maytenus thompsonii (luluhut)	6,253,939	3,481,824	—	—	—	—	6,253,939	3,481,824
Cynometra ramiflora (gulos)	5,646,131	3,331,393	290,308	153,595	25,541	26,186	5,961,981	3,445,968
Guamia mariannae (paipai)	5,762,308	2,953,801	23,388	17,805	—	—	5,785,696	2,956,591
Ficus tinctoria (hodda)	3,279,994	2,639,527	277,735	152,558	—	—	3,557,728	2,781,127
Annona squamosa (ates)	2,240,542	2,103,640	—	—	—	—	2,240,542	2,103,640
Melanolepis multiglandulosa (ålum)	1,272,634	551,370	299,843	167,343	—	—	1,572,477	655,464
Premna obtusifolia (åhgao)	713,014	372,608	834,744	155,630	24,098	17,771	1,571,856	457,098
Albizia lebbeck (trongkon kalaskas)	1,108,665	711,375	211,354	116,283	46,332	29,015	1,366,350	814,272
Hibiscus tiliaceus (pågo)	950,694	646,216	210,726	193,805	11,117	12,163	1,172,537	713,689
Ficus prolixa (nunu)	779,041	662,859	250,649	165,523	70,010	45,460	1,099,699	686,081
Aglaia mariannensis (mapunyao)	853,402	478,968	46,122	29,076	—	—	899,524	491,593
Delonix regia (atbut)	830,902	909,101	—	—	22,234	24,327	853,136	933,428
Psychotria mariana (aploghating)	733,609	559,481	100,511	92,455	—	—	834,120	626,433
Eugenia palumbis (agatelang)	799,750	766,651	—	—	—	—	799,750	766,651
Pandanus dubius (påhong)	276,967	303,034	452,416	227,539	—	—	729,383	426,733
Eugenia reinwardtiana (a'abang)	661,266	751,529	—	—	—	—	661,266	751,529
Spathodea campanulata (apär)	553,934	606,068	55,586	60,817	22,234	24,327	631,754	691,212
Pouteria obovata (lalaha)	553,934	335,016	23,888	17,871	11,117	12,163	588,939	348,827
Intsia bijuga (ifit)	323,394	322,796	172,275	138,264	34,215	27,391	529,883	470,918
Ochrosia mariannensis (langiti)	455,647	356,075	24,098	17,771	—	—	479,745	368,062
Aidia cochinchinensis (sumak)	415,451	323,394	—	—	—	—	415,451	323,394
Guettarda speciosa (panao)	276,967	303,034	77,973	46,430	11,117	12,163	366,057	327,824
Morinda citrifolia (lada)	276,967	303,034	85,797	56,606	—	—	362,764	306,944
Drypetes dolichocarpa (mwelel)	264,507	300,612	56,739	31,480	11,117	12,163	332,363	315,150
Pisonia grandis (umumu)	138,484	151,517	106,588	62,209	35,215	27,562	280,287	229,655
Cocos nucifera (niyog)	—	—	107,170	99,548	118,788	80,736	225,958	174,547
Hernandia labyrinthica (oschal)	—	—	169,872	167,194	53,085	60,331	222,957	227,070
Casuarina equisetifolia (gågu)	—	—	38,942	38,870	164,021	144,552	202,963	182,992
Pisonia umbellifera (birdlime tree)	132,253	150,306	53,085	48,049	10,617	12,066	195,955	164,941
Pipturus argenteus (amahåyan)	161,697	161,398	23,388	17,805	—	—	185,084	162,377
Citrus medica (rough lemon)	161,697	161,398	—	—	—	—	161,697	161,398
Hernandia sonora (oschal)	—	—	148,638	168,927	10,617	12,066	159,255	180,993
Polyscias grandifolia (pepega)	159,079	163,097	—	—	—	—	159,079	163,097
Areca catechu (pu-gwa')	138,484	151,517	—	—	—	—	138,484	151,517
Drypetes spp.	138,484	151,517	—	—	—	—	138,484	151,517
Neisosperma oppositifolia (fagot)	—	—	115,625	42,465	—	—	115,625	42,465

Table 8 (continued)—Number of live trees on forest land by species and diameter class in the Commonwealth of the Northern Mariana Islands

Scientific name (Chamorro common name)	1.0–4.9 inch diameter class		5.0–10.0 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
	NUMBER OF TREES							
Elaeocarpus joga (yoga)	—	—	42,468	31,597	—	—	42,468	31,597
Artocarpus altilis (lemai)	—	—	22,234	16,218	11,117	12,163	33,351	25,961
Artocarpus mariannensis (dogduk)	—	—	—	—	31,851	36,199	31,851	36,199
Pithecellobium dulce (kamachile)	—	—	23,888	17,871	—	—	23,888	17,871
Mammea odorata (chopak)	—	—	12,771	13,093	—	—	12,771	13,093
Dendrocnide latifolia (katot)	—	—	12,771	13,093	—	—	12,771	13,093
Adenanthera pavonina (kulalis)	—	—	—	—	11,117	12,163	11,117	12,163
Excoecaria agallocha (blinding tree)	—	—	10,617	12,066	—	—	10,617	12,066

— = not observed.

Diameter and Height

In 2015, the average diameter of all live trees ≥1-inch DBH in the CNMI was 2.8 inches (SE = 0.2), and the average height was 20.8 feet (SE = 0.7). More than 9 of 10 trees were <5 inches DBH (table 9). Diameter distribution was heavily weighted toward the smallest size class of 1.0–2.9 inches DBH (fig. 12), and the height distribution was heavily weighted toward the height class of 15–24 feet (fig. 13). The tallest and largest measured tree was an invasive *Adenanthera pavonina* (kulalis) at 30.7 inches DBH and 88 feet tall.

Mean tree diameter increased slightly by 0.3 inches DBH (SE = 0.2) between the 2004 and 2015 inventories, and mean height increased by 3.1 feet (SE = 1.0). The percentage of trees in the CNMI that were in the 1.0–2.9-inch DBH size class decreased by 8.3 percent (SE = 6.4), while the percentage in the 3.0–4.9-inch DBH size class increased by 7.2 percent (SE = 5.4), indicating maturation of the smallest trees (fig. 14). SE values are conservative.

There were significant differences in the percentage of trees by diameter class among islands in the CNMI. Saipan and Rota had proportionally more trees >10 inches DBH than Tinian. Saipan and Tinian had more trees <5 inches DBH than Rota. Rota had more trees between 5 and 10 inches DBH than Tinian or Saipan (fig. 15).

There were significant changes on Tinian in the distribution by diameter class between 2004 and 2015, with the 1.0–2.9-inch DBH size class decreasing by 10.3 percent (SE = 7.8), and the 3.0–4.9-inch DBH size class increasing by 9.2 percent (SE = 7.9), indicating maturation of the smallest trees.

Table 9—Abundance of live trees (mean and sample error [SE]) by diameter class in the Commonwealth of the Northern Mariana Islands

Diameter class	All trees	SE
INCHES	PERCENT	
1.0–2.9	65.1	4.6
3.0–4.9	26.7	4.0
5.0–6.9	5.4	1.0
7.0–8.9	1.5	0.3
9.0–10.9	0.7	0.2
11.0–12.9	0.2	0.1
13.0–14.9	0.2	0.1
15.0–16.9	0.1	0.0
≥17	0.1	0.1

Tree Damages

Assessing tree damages can provide insights into the status of many forest health issues and successional patterns. Damage agents, including insects, disease, vegetation suppression, humans, weather, and animals, can affect the health of each tree. Field crews assessed tree damages from bottom to top, prioritizing those

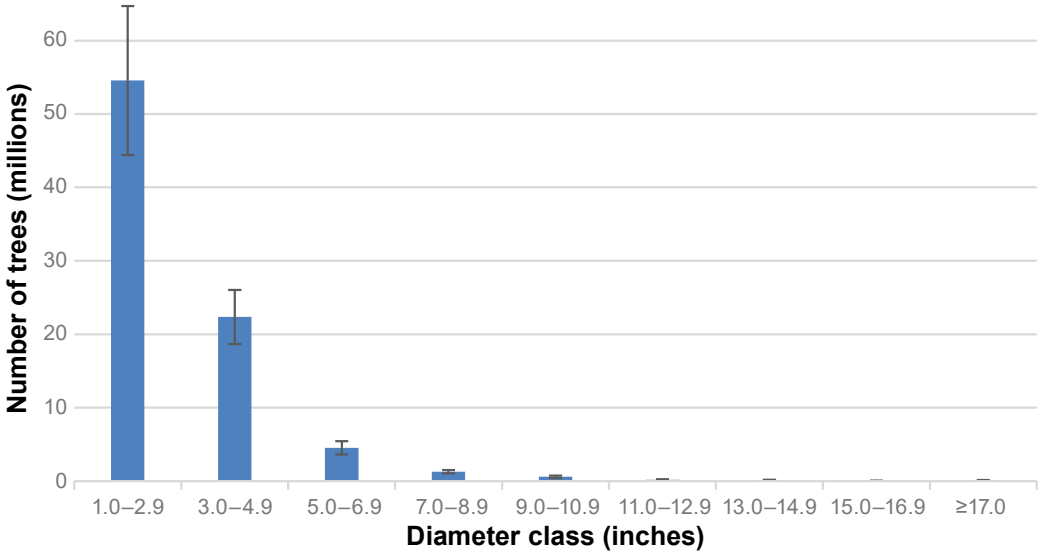

Figure 12—Number of live trees by diameter class in the Commonwealth of the Northern Mariana Islands. Error bars represent 68-percent confidence level.

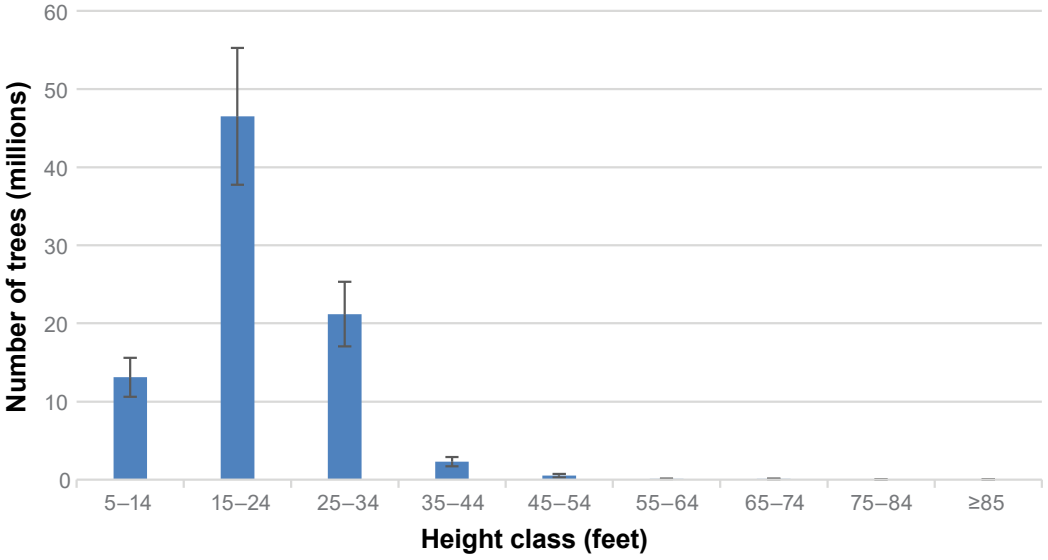

Figure 13—Number of live trees by height class in the Commonwealth of the Northern Mariana Islands. Error bars represent 68-percent confidence level.

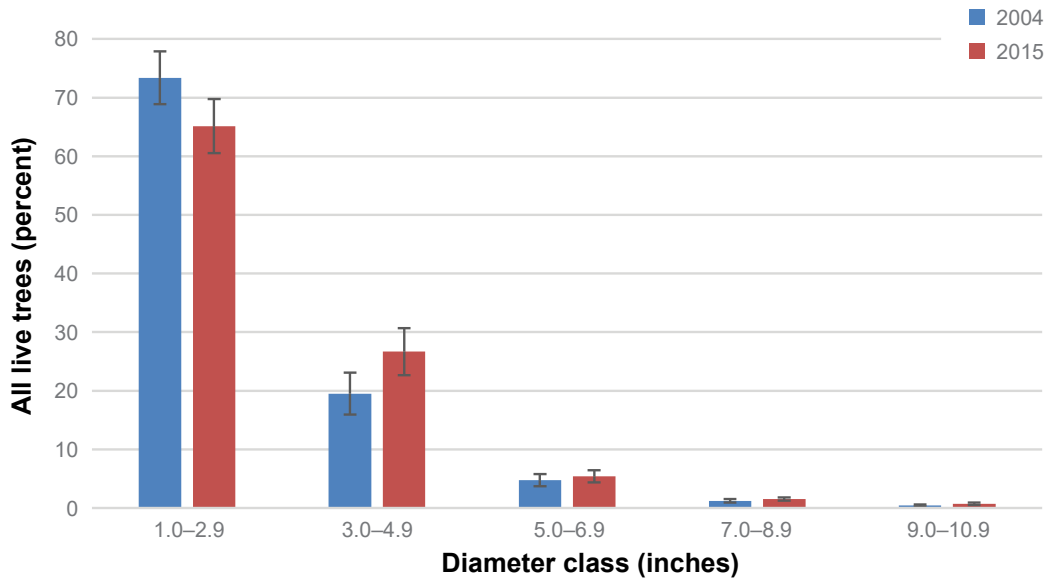

Figure 14—Live trees by diameter class in the Commonwealth of the Northern Mariana Islands. Error bars represent 68-percent confidence level.

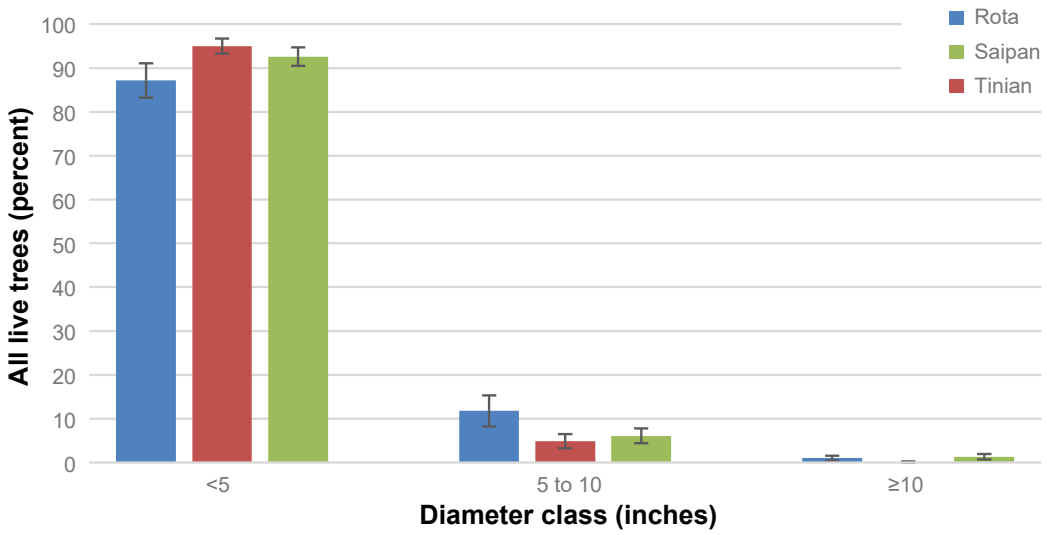

Figure 15—Live trees by diameter class on Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands. Error bars represent 68-percent confidence level.

that lead to mortality, then those that reduce near-term growth, and finally those that hinder the tree from becoming a marketable product. Up to three damage agents were recorded per assessed tree. Crews recorded root and butt damages, cankers, and stem decay when any evidence was detected. Crews coded other damage agents only if they met a threshold that would lead to death or reduced growth. Details on this field protocol and thresholds by damage agent can be found in the field manual (USDA FS 2015).

In 2015, 62.9 percent (SE = 4.2) of all live trees that were ≥1-inch DBH in the CNMI had a damage coded. The most prevalent type of damage was stem decay, which affected 52.7 percent (SE = 4.2) of all trees (table 10). The percentage of trees with damage nearly doubled from 2004. This may be indicative of aging *Leucaena leucocephala* stands on Saipan and Tinian that can be susceptible to rot, or it may stem from a difference in the way the crews in 2004 and 2015 interpreted when to code rot—stem decay was recorded if trees had any visible evidence in 2015. Invasive *L. leucocephala* trees made up 31.4 percent (SE = 6.4) of all trees with stem decay, which is comparable to its percentage among all live trees overall.

Vines damaged 17.4 percent (SE = 3.9) of all trees in 2004 and 15.1 percent (SE = 4.1) of trees in 2015 (Donnegan et al. 2011). Weather was a source of tree damage in 2004 (5.1 percent [SE = 2.1]); two typhoons caused major damages across the Mariana Islands that year. Weather damage was unrecorded in 2015 even though at least five significant typhoons occurred in the region between inventories. Unknown causes accounted for almost 10 percent of tree damages in 2004 (Donnegan et al. 2011). In 2015, a more detailed tree damage methodology led to a comparable result, with 7.6 percent (SE = 1.6) of trees observed with broken tops and 3.3 percent (SE = 1.0) damaged by suppression from the shade of competing trees.

There were 16 species of trees with damage estimated to more than half of those tallied, but results for damage types other than stem decay had high sample error (table 11). There was a high rate of root disease in *Intsia bijuga* (ifit), and vine damage in *Albizia lebbeck* (trongkon kalaskas), *L. leucocephala*, *Melanolepis multiglandulosa* (ålum), and *Premna obtusifolia* (åhgao).

Pacific Islands-Specific Damages (*Phellinus noxius*)

A priority damage is a parameter specific to the Pacific Islands inventory that describes a damage that does not meet the national minimum thresholds for recording damage but is of special interest to this region (Cannon et al. 2022, USDA FS 2015). Of the eight priority damages on the FIA list, only *Phellinus noxius* was recorded in the CNMI, and only one *Cynometra ramiflora* (gulos) tree was observed with this root rot. There were no cycads observed in this study, although an endemic cycad species (*Cycas micronesica* K.D. Hill) occurs in the Mariana Islands and is known to occur at least on Rota. An outbreak of invasive cycad scale, *Aulacaspis yasumatsui,* devastated the cycad population on Guam between the 2002 and 2013 inventories there. Similarly,

Table 10—Abundance (mean and sample error [SE]) of live trees (≥1-inch DBH) by damage type on Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands (CNMI)

Damage type	Rota		Saipan		Tinian		CNMI	
	Total	SE	Total	SE	Total	SE	Total	SE
	PERCENT							
Any damage	46.7	6.7	58.4	7.5	82.4	6.8	62.9	4.2
Stem decay	39.5	7.1	42.3	6.2	76.2	7.6	52.7	4.2
No damage	53.3	6.7	41.6	7.5	17.6	6.8	37.1	4.2
Vine damage	6.3	1.8	18.5	6.8	19.2	10.0	15.2	4.1
Dead top	3.8	1.1	11.0	3.8	19.5	3.5	11.7	2.2
Broken top	0.9	0.4	8.6	2.4	12.3	3.3	7.6	1.6
Root/butt diseases	3.3	2.0	1.9	1.5	5.9	3.1	3.6	1.3
Competition	0.5	0.5	5.2	2.5	3.4	1.4	3.3	1.0
Other damages and symptoms	1.7	1.0	3.0	1.3	1.3	0.8	2.1	0.7
Foliage diseases	—	—	0.4	0.4	2.3	1.5	0.9	0.6
Abiotic damage	—	—	2.0	2.0	—	—	0.8	0.8
Defoliators	1.4	1.4	—	—	0.6	0.6	0.6	0.4
Parasitic plants	—	—	0.9	0.9	—	—	0.3	0.3
General diseases	0.1	0.1	0.0	0.0	0.8	0.7	0.3	0.2
Domestic animals	—	—	—	—	0.6	0.6	0.2	0.2
Open wound	0.0	0.0	0.1	0.1	—	—	0.0	0.0
General insects	—	—	—	—	—	—	—	—
Boring insects	—	—	—	—	—	—	—	—
Cankers	—	—	—	—	—	—	—	—
Decline complexes/dieback/wilts	—	—	—	—	—	—	—	—
Fire	—	—	—	—	—	—	—	—
Wild animals	—	—	—	—	—	—	—	—
Human activities	—	—	—	—	—	—	—	—

Note: CNMI values represent the islands of Rota, Saipan, and Tinian combined.
DBH = diameter at breast height, — = not observed.

the coconut rhinoceros beetle, *Oryctes rhinoceros,* has damaged many coconut trees on Guam. Damage from the beetles was not observed on coconut trees on Rota, Saipan, or Tinian during our study, but an infestation on Rota is currently ongoing.[1]

Epiphyte Loading

Epiphytes are vascular plants that grow on trees or other plants, and include native orchids, forbs, and vines. Epiphytes are common in tropical forests and often make up a substantial component of total species diversity in lowland tropical rainforests. However, when epiphyte load becomes excessive, it can cause tree damage, mortality, and lack of growth. Epiphyte load was estimated for each tree that was ≥1-inch DBH using a composite score of none (0), light (1), or heavy (2) for epiphyte loads in three sections of each tree—the bottom, middle, and top—for a total epiphyte load composite score that ranges from 0 to 6. In the CNMI, total epiphyte load composite scores for about 1 percent of all trees were heavy (6), 13 percent were moderate (4–5), 55 percent were light (1–3), and 31 percent were none (0) (fig. 16). *Melanolepis multiglandulosa* and *Premna obtusifolia* were the only two species, out of the 10 live tree species with sample sizes that were greater than 30, with average

[1] **Miller, R. 2021.** Personal communication. Professor of entomology, Western Pacific Tropical Research Center, UOG Station, Mangilao, Guam, 96923, millerr@triton.uog.edu.

Table 11—Abundance (mean and sample error [SE]) of live trees (≥1-inch DBH) by species (n ≥ 20) and damage type in the Commonwealth of the Northern Mariana Islands

Tree species	Root/butt diseases		Stem decay		Shade		Other damages		Broken top		Dead top		Vine damage		Any damage		No damage	
	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	PERCENT																	
Albizia lebbeck	11.8	11.8	92.9	2.4	0.0	0.0	1.0	1.0	12.8	12.8	12.6	7.1	28.3	17.1	94.8	3.2	5.2	3.2
Premna obtusifolia	12.3	9.2	73.2	13.2	8.8	8.8	4.9	2.8	2.9	1.6	0.8	0.8	26.2	10.1	86.4	9.8	13.6	9.8
Leucaena leucocephala	4.6	2.4	73.5	6.4	2.1	1.2	1.8	0.9	12.8	2.7	22.9	2.7	25.0	8.8	83.5	5.7	16.5	5.7
Melanolepis multiglandulosa	–	–	61.5	24.1	10.1	10.1	–	–	0.7	0.7	0.8	0.8	45.0	15.4	67.4	22.6	32.6	22.6
Maytenus thompsonii	–	–	62.3	8.8	–	–	–	–	–	–	–	–	–	–	62.3	8.8	37.7	8.8
Guamia mariannae	0.2	0.2	41.0	17.0	4.7	2.8	0.2	0.2	2.3	2.3	7.5	3.8	9.7	4.1	52.0	12.4	48.0	12.4
Ficus prolixa	–	–	47.6	15.6	–	–	–	–	4.3	3.4	3.3	2.9	5.2	3.8	48.6	16.0	51.4	16.0
Hibiscus tiliaceus	–	–	36.4	22.0	–	–	12.8	12.8	0.9	0.9	0.9	0.9	11.3	11.3	47.6	24.0	52.4	24.0
Cynometra ramiflora	–	–	25.6	10.7	2.7	2.7	0.8	0.4	14.5	3.1	3.1	2.8	11.9	5.7	45.7	11.0	54.3	11.0
Ficus tinctoria	–	–	21.8	5.5	7.8	7.8	12.0	12.0	–	–	7.4	7.2	5.6	5.4	42.5	6.1	57.5	6.1
Pandanus tectorius	5.3	5.6	15.8	8.2	–	–	–	–	–	–	–	–	0.2	0.2	18.3	8.4	81.7	8.4
Hernandia labyrinthica	–	–	14.3	14.3	–	–	–	–	4.8	4.8	4.8	4.8	–	–	14.3	14.3	85.7	2.3
Pandanus dubius	3.0	1.4	10.3	5.7	–	–	2.9	2.9	–	–	–	–	1.5	1.5	11.7	5.9	88.3	5.9
Any tree	3.6	1.3	52.7	4.2	3.3	1.0	2.1	0.7	7.6	1.6	11.7	2.2	15.2	4.1	62.9	4.2	37.1	4.2

DBH = diameter at breast height, — = not observed.

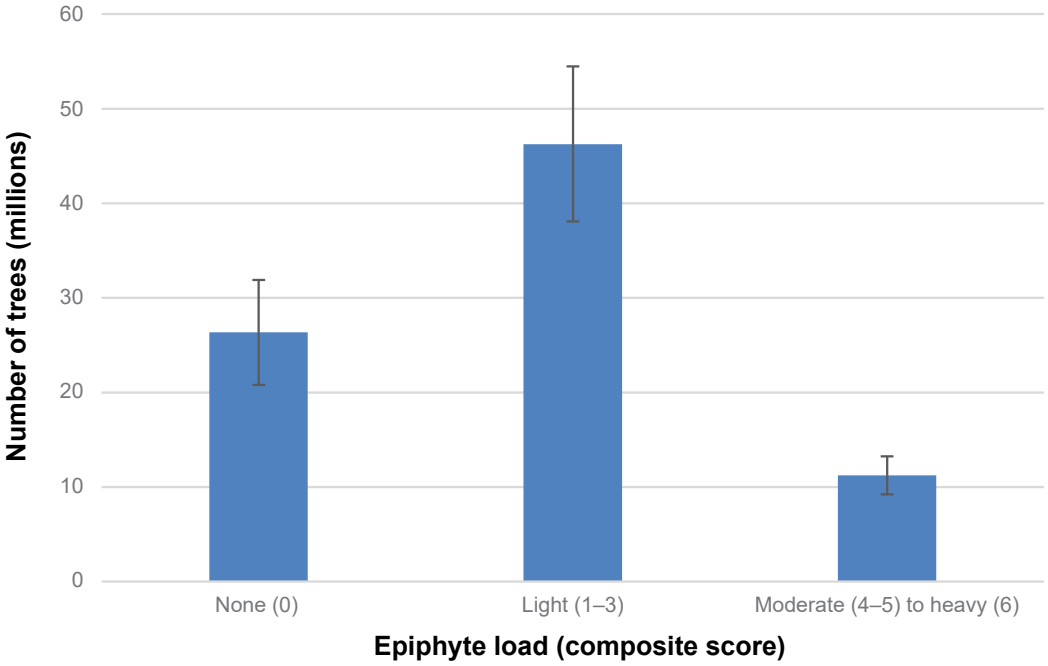

Figure 16—Number of live trees ≥1-inch diameter at breast height by epiphyte load composite score in the Commonwealth of the Northern Mariana Islands. Error bars represent 68-percent confidence level.

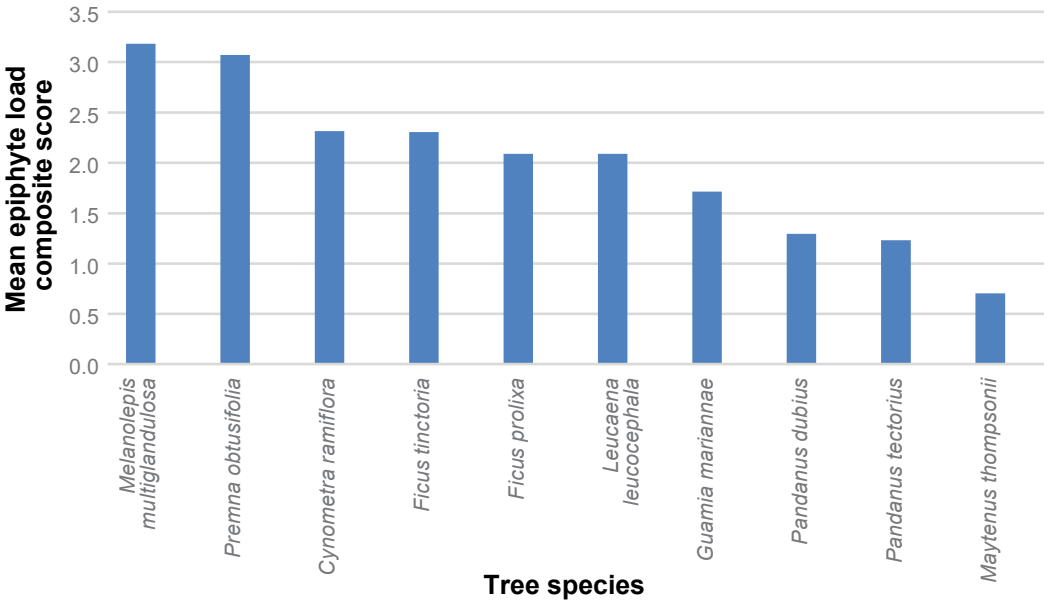

Figure 17—Mean epiphyte load composite score (n > 30) for trees ≥1-inch diameter at breast height by species in the Commonwealth of the Northern Mariana Islands.

epiphyte load composite scores greater than 3 (fig. 17). The endemic *Maytenus thompsonii* (luluhut) was the only tree species of the 10 with a mean composite score less than 1. The percentage of trees with light epiphyte loads was higher in 2015 (64 percent) than in 2004 (55 percent), as was the percentage with no epiphytes, increasing to 31 percent in 2015 from 20 percent in 2004 (Donnegan et al. 2011). We observed the same trend on Guam from 2002 to 2013, although it was more pronounced there, with increases of 23 percent with light epiphyte loads and 27 percent with no epiphyte loads. Epiphyte loading is generally correlated with variation in precipitation, with greater loading in forests with higher and less temporally variable precipitation.

Growth, Mortality, and Removals

We estimated that there were 33,573,063 (SE = 4,668,416) new trees ≥1-inch DBH in the CNMI from 2004 to 2015; 30,694,230 (SE = 5,223,128) trees lost to mortality; and 1,842,665 (SE = 1,322,404) trees removed by people. The

sum of these categories resulted in a total net gain of 1,036,168 (SE = 4,407,174) trees, but the SE value was more than four times the value of the estimate, so we cannot know for sure if there was an increase or decrease in the number of trees in the CNMI during this time.

The tree species with the largest significant net change in tree abundance was *Pandanus dubius* (påhong), with a net loss. Four of the five most salient net changes by species were net losses, including *Cocos nucifera* (niyog), *Guettarda speciosa* (panao), and *Eugenia reinwardtiana* (a'abang) (table 12). *Ficus tinctoria* (hodda) had the second most salient net change, an increase.

We estimated a 758,117-ton (SE = 95,852) increase in tree biomass (live, aboveground, and dry weight) from 2004 to 2015, a 450,365-ton (SE = 64,799) loss from tree mortality, and a 45,351-ton (SE = 27,269) loss from tree removals (Chave et al. 2014). The sum of these categories resulted in a total net gain of 262,401 (SE = 82,580) tons of tree biomass to CNMI forests. The weight of forest carbon (total, gained, or lost) is about half (47 percent in CNMI) the weight of the respective biomass.

Sixteen tree species had significant net changes in biomass between inventories (with an SE/estimate ratio <0.9), of which 13 were positive. The tree species with the largest significant net change in biomass was *L. leucocephala*, followed by the endemic *M. thompsonii*, both with net gains (table 13). *Pandanus dubius* had the largest significant loss in biomass. However, there was a clear trend of more trees transitioning into a larger diameter class between 2004 and 2015 (fig. 18).

In 2015, 4.8 percent (SE = 1.2) of all trees ≥5 inches DBH were standing dead trees, which was slightly lower than 2004 (6.8 percent, SE = 2.1) (Donnegan et al. 2011). We inventoried 13 species of standing dead trees ≥1-inch DBH. The most common species of dead trees were *Premna obtusifolia* (åhgao), with 19 percent of inventoried standing dead trees; *L. leucocephala*, with 13 percent; and *Adenanthera pavonina*, *Intsia bijuga*, and *Pandanus tectorius* (kaffo'), with 10 percent each (fig. 19). About 46 percent of dead trees ≥5 inches DBH were killed by disease, 21 percent were killed by vegetation suppression, 21 percent had an unknown cause of death, and 13 percent were killed by silvicultural or land clearing activity. All trees <7 inches DBH had similar mortality rates, and larger trees had lower mortality rates, which is unusual for a tropical forest (fig. 20).

Table 12—Growth, mortality, removals, and net change in abundance (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands from 2004 to 2015 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Chamorro common name	2004		2015		Growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
		NUMBER OF TREES											
Pandanus dubius	Påhong	388,084	218,839	123,069	75,745	—	—	−265,016	148,830	—	—	−265,016	148,830
Ficus tinctoria	Hodda	2,198,843	2,313,216	3,670,734	2,982,023	2,062,048	1,370,404	−590,157	634,198	—	—	1,471,891	833,548
Cocos nucifera	Niyog	166,322	94,104	109,311	68,441	10,617	12,066	−44,824	29,233	−22,804	24,951	−57,011	38,168
Guettarda speciosa	Panao	240,728	185,630	219,494	182,921	—	—	−21,234	15,798	—	—	−21,234	15,798
Eugenia reinwardtiana	A'abang	1,249,166	1,100,544	661,266	751,529	132,253	150,306	−720,153	554,549	—	—	−587,900	441,095
Aidia cochinchinensis	Sumak	—	—	426,103	331,686	426,103	331,686	—	—	—	—	426,103	331,686
Psychotria mariana	Aploghating	390,507	298,407	833,656	626,054	443,148	350,998	—	—	—	—	443,148	350,998
Pithecellobium dulce	Kamachile	46,977	39,650	11,402	12,475	—	—	−35,575	28,177	—	—	−35,575	28,177
Intsia bijuga	Ifit	532,036	469,397	480,324	430,696	—	—	−51,713	41,016	—	—	−51,713	41,016

— = not observed.

Table 13—Growth, mortality, removals, and net change in biomass (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands from 2004 to 2015 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Chamorro common name	2004		2015		Growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
		LIVE, ABOVEGROUND DRY WEIGHT (TONS)											
Leucaena leucocephala	Tångantångan	335,033	64,194	486,958	98,789	345,668	71,790	–184,337	39,688	–12,939	10,439	148,392	45,637
Maytenus thompsonii	Luluhut	27,007	16,347	46,482	26,400	25,512	14,437	–6,037	4,336	—	—	19,476	10,676
Pandanus dubius	Påhong	15,046	8,455	5,237	3,263	1,056	655	–10,865	6,062	—	—	–9,809	5,476
Aglaia mariannensis	Mapunyao	11,356	6,955	15,822	9,904	4,466	3,063	—	—	—	—	4,466	3,063
Ochrosia mariannensis	Langiti	1,370	1,028	6,687	4,752	5,318	3,838	—	—	—	—	5,318	3,838
Aidia cochinchinensis	Sumak	—	—	913	666	913	666	—	—	—	—	913	666
Ficus tinctoria	Hodda	23,540	20,848	38,619	31,361	19,385	13,410	–4,305	3,403	—	—	15,079	11,027
Hibiscus tiliaceus	Pågo	18,428	17,677	32,747	20,829	26,191	15,780	–11,871	12,193	—	—	14,320	10,638
Pithecellobium dulce	Kamachile	3,362	3,183	2,114	2,313	943	884	–2,191	1,822	—	—	–1,248	970
Melanolepis multiglandulosa	Ålum	13,814	9,537	17,949	10,627	11,917	5,973	–7,782	4,872	—	—	4,135	3,243
Psychotria mariana	Aploghating	6,072	5,953	9,448	8,482	3,376	2,662	—	—	—	—	3,376	2,662
Eugenia palumbis	Agatelang	940	1,068	1,304	1,236	648	532	–284	322	—	—	365	299
Drypetes dolichocarpa	Mwelel	3,905	4,273	6,638	6,384	2,733	2,263	—	—	—	—	2,733	2,263
Eugenia reinwardtiana	A'abang	2,888	2,908	1,805	2,051	1,063	934	–2,146	1,837	—	—	–1,083	905
Neisosperma oppositifolia	Fagot	3,785	1,829	14,196	10,304	11,274	9,235	–864	862	—	—	10,411	9,266
Casuarina equisetifolia	Gågu	76,786	68,999	92,834	83,376	18,246	14,937	–2,198	2,497	—	—	16,048	14,378

— = not observed.

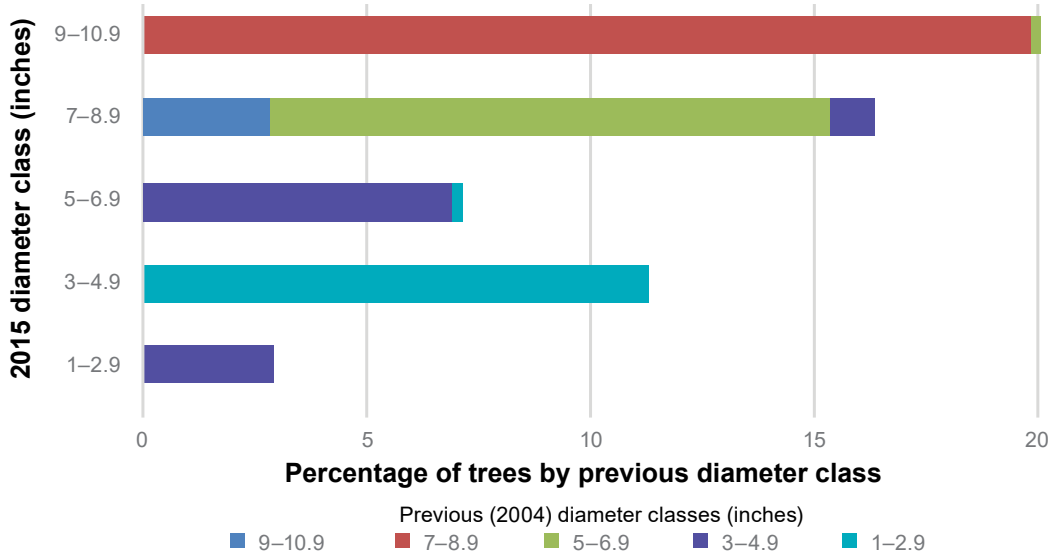

Figure 18—Trees that transitioned to a different diameter class between the 2004 and 2015 USDA Forest Service Forest Inventory and Analysis inventories in the Commonwealth of the Northern Mariana Islands.

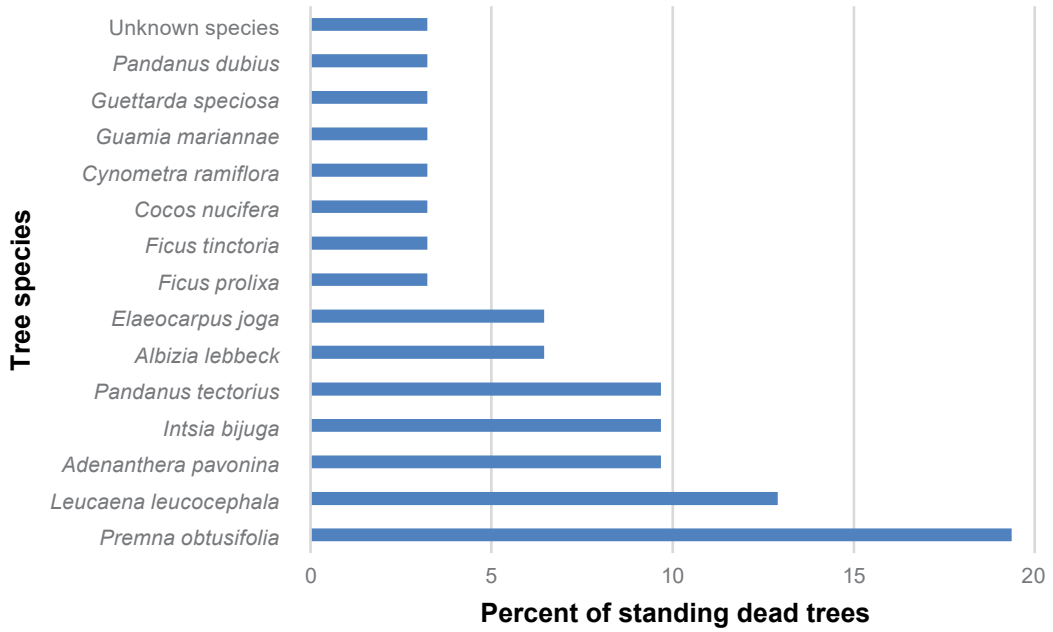

Figure 19—Standing dead trees by species that were inventoried in the Commonwealth of the Northern Mariana Islands.

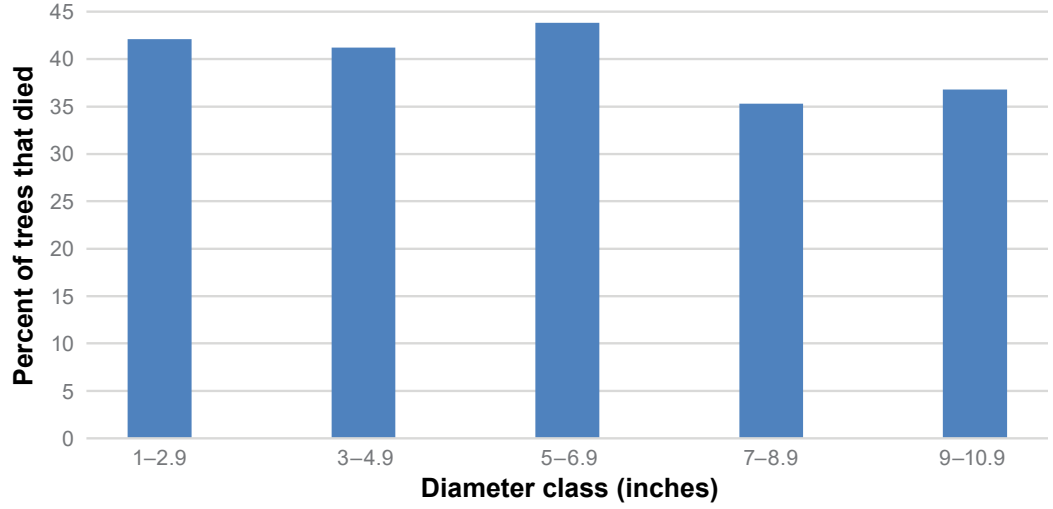

Figure 20—Trees that died between the 2004 and 2015 USDA Forest Service Forest Inventory and Analysis inventories by diameter class in the Commonwealth of the Northern Mariana Islands.

Removed trees composed about 0.8 percent of all inventoried trees in 2015. There was only one tree species removed by people between the 2004 and 2015 inventories, *L. leucocephala*. There were 12 inventoried trees harvested or killed during silvicultural or land clearing activity.

Forest Structure

Stand Size Class

The USDA Forest Service FIA program uses six stand size classes based on the predominant size of all live trees and saplings. Forests inventoried in the CNMI were all considered hardwood forests, with stand size classes of nonstocked, class 1 (1.0–4.9-inch DBH), class 2 (5.0–10.9-inch DBH), class 3 (11.0–19.9-inch DBH), class 4 (20.0–39.9-inch DBH), and class 5 (≥40-inch DBH). Almost all the forest area in the CNMI was defined as stand size class 1 (saplings) or class 2. There were no class 4 or class 5 forest plots measured in the CNMI (table 14).

Volume, Biomass, Carbon, Stem Density, and Basal Area

In 2015, we estimated 33,576,059 cubic feet (SE = 8,525,157) of live tree volume in CNMI forests and 1,617,573 tons (SE = 224,181) of live, dry, aboveground biomass (761,283 tons of carbon [SE=104,802]). In terms of annual productivity, in the CNMI, tree biomass grew about 6.0 percent, and about 3.9 percent was lost to mortality (3.5 percent) and tree removals, for a net increase of 2.1 percent.

There were no significant changes in stem density between the 2004 and 2015 inventories, but there was a significant increase in basal area, which indicates that the increase in biomass was due primarily to tree growth rather than ingrowth of trees (table 15).

Vegetation Profile

Vegetation profile data collected on each subplot include two different datasets: (1) dominant vascular species composition and (2) growth habit by vegetation height layer. Dominant vascular species composition is collected for the four most abundant plant species in each growth habit (grasses, shrubs, forbs, and tree seedlings and saplings) that meet a 3-percent cover threshold. The height layer is listed where the most species cover occurs. The coverage of each growth habit is also described by height layer along with an overall aerial estimate across the entire subplot.

Table 14—Forest area (mean and sample error [SE]) by stand size class in the Commonwealth of the Northern Mariana Islands (CNMI)

Stand size class (DBH)	Rota		Saipan		Tinian		CNMI	
	Area	SE	Area	SE	Area	SE	Area	SE
	PERCENT							
Nonstocked	—	—	7	7	—	—	3	3
1 (1.0–4.9 inches)	31	17	55	13	80	14	57	9
2 (5.0–10.9 inches)	69	17	33	13	20	14	38	9
3 (11.0–19.9 inches)	—	—	6	5	—	—	2	2
4 (20.0–39.9 inches)	—	—	—	—	—	—	—	—
5 (≥40 inches)	—	—	—	—	—	—	—	—

Note: CNMI values represent the islands of Rota, Saipan, and Tinian combined.
DBH = diameter at breast height, — = not observed.

Table 15—Stem density and basal area (mean and sample error [SE]) estimates from the 2004 and 2015 USDA Forest Service, Forest Inventory and Analysis inventories in the Commonwealth of the Northern Mariana Islands

	2004	SE	2015	SE	Difference	SE
Stem density (trees per acre)	1,341	215	1,402	193	61	87
Basal area (ft^2 per acre)	70	7	86	9	17	6

Dominant Vascular Plant Species Composition

We recorded 132 dominant vascular plant species in CNMI forests in 2015; Donnegan et al. (2011) recorded 107 such species in 2004. About 37 percent of dominant plant species surveyed in the CNMI were trees; 18 percent were shrubs; 36 percent were forbs; and 11 percent were grasses or grass-like plants. Among the 20 most recorded dominant tree seedling/sapling species, 2 were endemic to the Mariana Islands, 1 was endemic to Micronesia, and 1 was an introduced invasive (table 16). One Marianas endemic and nine introduced invasive species were among the twenty most recorded dominant nontree species (table 17).

Seedlings and saplings of *Leucaena leucocephala* (tångantångan) covered the most forest area of any dominant vascular plant species or seedling/sapling, with about three times the coverage of the next most dominant seedling/sapling species, *Pandanus tectorius* (kaffo') and the most dominant nontree species, *Rivina humilis* (rougeplant). Two species of *Pandanus*; two trees endemic to the Mariana Islands, *Guamia mariannae* (paipai) and *Maytenus thompsonii* (luluhut); *Melanolepis multiglandulosa* (ålum); and *Cynometra ramiflora* (gulos) were the other dominant species covering much of the forest understory in the CNMI.

The endemic climbing jasmine *Jasminum marianum* (banago) made up a substantial proportion of nontree forest understory and was 1 of 9 vines included in the 20 most dominant nontree plant species. This preponderance of vines may explain why one-third of forest area was disturbed by vegetation suppression. Nine of the most dominant nontree species, including five vine species, were introduced invasives, indicating a substantially

Table 16—Twenty most dominant seedling/sapling tree species by forest area (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands

Scientific name	Chamorro common name	Forest area	SE	Status
		PERCENT		
Leucaena leucocephala	Tångantångan	23.5	4.3	I*
Pandanus tectorius	Kaffo'	6.6	2.2	N
Guamia mariannae	Paipai	5.9	1.9	C
Melanolepis multiglandulosa	Ålum	3.8	1.5	N
Cynometra ramiflora	Gulos	3.4	1.7	N
Pandanus dubius	Påhong	2.7	1.3	N
Maytenus thompsonii	Luluhut	2.2	0.8	C
Premna obtusifolia	Åhgao	1.6	0.4	N
Hibisucs tiliaceus	Pågo	1.4	0.6	N
Morinda citrifolia	Lada	1.3	0.6	N
Albizia lebbeck	Trongkon kalaskas	1.3	0.9	I
Pemphis acidula	Nigas	1.1	1.1	N
Ficus tinctoria	Hodda	1.1	0.5	N
Cocos nucifera	Niyog	1.1	0.8	N
Ficus prolixa	Nunu	0.9	0.7	N
Aidia cochinchinensis	Sumak	0.9	0.6	N
Scaevola taccada	Nanåso	0.9	0.9	N
Psychotria mariana	Aploghating	0.8	0.5	M
Neisosperma oppositifolia	Fagot	0.6	0.3	N
Intsia bijuga	Ifit	0.5	0.3	N

C = endemic to Marianas, I = introduced, I* = invasive, M = endemic to Micronesia, N = native.

Sources: Chamorro common names: Falanruw et al. (1990), Raulerson and Rinehart (2021); endemism: Costion and Lorence (2012); other status: USDA FS PIER (2018).

Table 17—Twenty most dominant nontree plant species by forest area (mean and sample error [SE]) and USDA Natural Resource Conservation Service growth habit in the Commonwealth of the Northern Mariana Islands

Scientific name	Chamorro common name	Forest area	SE	Growth habit	Status
		PERCENT			
Rivina humilis	Rogueplant	7.5	3.1	Shrub	U
Blechum pyramidatum	Browne's blechum	6.3	1.9	Forb	U
Mikania micrantha	Mile-a-minute vine	3.6	1.0	Forb (vine)	I*
Jasminum marianum	Banago	3.0	0.8	Shrub (vine)	C
Urochloa maxima	Guinea grass	2.9	1.6	Grass	I*
Phymatosorus scolopendria	Monarch fern	2.8	1.2	Forb (fern)	U
Triphasia trifolia	Limon di china	2.7	2.2	Shrub	I*
Ipomoea indica	Oceanblue morning-glory	2.7	1.1	Forb (vine)	U
Oplismenus compositus	Running mountaingrass	2.6	1.9	Grass	U
Lantana camara	Lantana	2.2	1.1	Shrub	I*
Operculina turpethum var. *ventricosa*	Paper rose	2.2	0.9	Forb (vine)	I*
Pennisetum purpureum	Elephant grass	2.2	1.5	Grass	U
Ruellia prostrata	Prostrate wild petunia	2.0	1.4	Forb	U
Coccinia grandis	Ivy gourd	1.9	0.8	Forb (vine)	I*
Centrosema molle	Centro	1.8	1.0	Forb (vine)	I*
Bidens alba	Romerillo	1.8	1.2	Forb	I*
Nephrolepis biserrata	Giant swordfern	1.6	1.6	Forb (fern)	U
Passiflora suberosa	Corkystem passionflower	1.3	0.6	Forb (vine)	I*
Stictocardia tiliifolia	Spottedheart	1.3	0.9	Forb (vine)	U
Flagellaria indica		1.2	0.4	Shrub (vine)	U

Note: C = endemic to Marianas, I* = invasive, U = uncertain.
Source: Chamorro common names: Falanruw et al. (1990), Raulerson and Rinehart (2021); endemism: Costion and Lorence (2012).

altered forest ecology. Two additional invasive vine species, *Mucuna pruriens* (akangkang dangkulo) and *Antigonon leptopus* (chain of love), were recorded at low levels in the inventory but are now considered species of concern, capable of damaging forests.[2] Three dominant understory plant species were grasses, which is another indication of disturbed, patchy forests and could be related to the presence of livestock.

Vegetation Growth Habit and Height Layer

Trees comprised the greatest vegetation cover in CNMI forests; the greatest tree cover was more than 6 feet in height in layers 3 (6.1 to 16.0 feet aboveground) and 4 (more than 16.0 feet aboveground) (table 18). Vegetation cover in layer 3, however, was highest for all growth habits combined. The total mean ground cover from layer 1 (0 to 2.0 feet aboveground) was the same as layer 2 (2.1 to 6.0 feet aboveground) (table 19). This and the high shrub and grass cover values indicate relatively short-stature and open tropical rainforest with dense understory.

Invasive Species

Invasive species are a threat to native biodiversity and forest health, which is why the FIA program incorporated an invasive plant species protocol in the most recent measurement cycle. The CNMI Department of Lands and Natural Resources, Division of Agriculture, Forestry Program provided a priority list of invasive plants and trees to include in the inventory. Any invasive

[2] **Bevacqua, R. 2021.** Personal communication. Forest health and agroforestry specialist, University of Guam, UOG Station, Mangilao, Guam 96923, bevacquar@triton.uog.edu.

Table 18—Vegetation growth habit by height-layer forest area (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands

Growth habit	Layer 1: 0.0–2.0 ft	SE	Layer 2: 2.1–6.0 ft	SE	Layer 3: 6.1–16.0 ft	SE	Layer 4: >16.0 ft	SE	Overall aerial	SE
	PERCENT									
Tree	6	1	17	2	48	3	47	4	69	4
Shrub	9	2	12	3	7	2	3	1	20	4
Grass	9	3	4	2	1	1	0	0	11	3
Forb	19	3	12	3	10	1	6	1	33	4

Table 19—Vegetation height layer by forest area (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands

Vegetation height layer	Forest area	SE
	PERCENT	
1 (0.0–2.0 ft)	45	4
2 (2.1–6.0 ft)	45	4
3 (6.1–16.0 ft)	67	4
4 (>16 ft)	56	5
Overall aerial[a]	133	5

[a]Overall aerial value includes overlap of growth habits, indicating structural complexity.

Table 20—Invasive plant species presence and coverage by forest area (mean and sample error [SE]) in the Commonwealth of the Northern Mariana Islands

Presence or coverage	Total forest area	SE
	PERCENT	
Invasive plants present	84.9	3.5
Covered in invasive plants	54.6	8.0

Note: See footnote 3.

plant species observed from the list with greater than 0 and less than 1.5 percent cover was recorded as 1 percent cover. In 2015, invasive plants covered more than half of the CNMI's total forest area. Eighty-five percent (SE = 4) of total forest area had at least one invasive species present indicating how widespread they were across the landscape (table 20).[3] We recorded 28 species of invasive plants, of which *L. leucocephala* was by far the most widespread, covering about a quarter of the total forest area on Saipan and the entire CNMI and approaching half of total forest area cover on Tinian (table 21). *L. leucocephala* forms pure stands on Tinian and Saipan that shade out other vegetation on nonrocky soils (fig. 21) but is in decline due to attack from psyllids (CNMI SWARS 2015).

The CNMI forest action plan highlights the invasive vine *Coccinia grandis* (ivy gourd) as the most problematic invasive species on Saipan after *L. leucocephala*. Inventory results confirmed its presence but indicate that total coverage of *C. grandis* is far lower than the 80-percent estimate in the plan (CNMI 2015). In 2015, two other invasive species covered significantly more forest area than *C. grandis* across the CNMI, *L. leucocephala* and another herbaceous vine, *Mikania micrantha* (mile-a-minute vine).

Conclusion

We found that two-thirds of total forest area in the CNMI had a disturbance in the 2015 inventory, but disturbance trends varied greatly among the islands of Rota, Saipan, and Tinian. Rota was the least disturbed island and, according to vegetation maps, contained the most native forest. More than half of Saipan's forest area was disturbed, with more than a quarter of the forest area affected by disturbance from vines. Tinian was the most disturbed island, with at least one disturbance recorded on every plot. The percentage of disturbed forest area in the CNMI doubled since 2004. Some of this can be attributed to the procedural change associated with tree

[3]Invasive species presence is recorded if any trace or more is observed within forested 24-ft radius subplots. Only one plot per 2,000 acres of forest is sampled, with the percent of total forest area estimates generated at the state/island level from this sample.

Table 21—Forest area cover (mean and sample error [SE]) by invasive plant species on Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands

Invasive species	Rota		Saipan		Tinian		Total	
	Forest area	SE	Forest area	SE	Forest area	SE	Forest area	SE
	PERCENT							
Leucaena leucocephala	0.5	0.3	24.8	7.2	43.2	8.8	24.8	4.4
Mikania micrantha	2.3	1.0	3.6	1.2	6.1	2.6	4.1	1.0
Urochloa maxima	—	—	0.6	0.4	7.9	4.0	3.0	1.6
Triphasia trifolia	9.2	8.3	1.0	0.8	0.1	0.0	2.8	2.2
Lantana camara	—	—	1.6	1.0	5.1	2.8	2.4	1.1
Operculina turpethum var. ventricosa	—	—	2.6	1.5	3.7	2.1	2.3	1.0
Coccinia grandis	—	—	5.1	2.0	—	—	2.0	0.8
Centrosema molle	—	—	—	—	5.5	2.7	1.9	1.0
Bidens alba	1.8	1.8	0.2	0.2	3.7	3.0	1.8	1.2
Passiflora suberosa	0.6	0.2	0.6	0.3	3.6	1.6	1.7	0.6
Spathodea campanulata	—	—	2.5	2.5	—	—	1.0	1.0
Epipremnum pinnatum	2.6	2.6	0.4	0.3	—	—	0.8	0.7
Chromolaena odorata	0.3	0.1	0.3	0.2	1.7	1.0	0.8	0.4
Antigonon leptopus	—	—	0.0	0.0	2.1	2.1	0.8	0.7
Adenanthera pavonina	—	—	1.8	1.8	—	—	0.7	0.7
Pithecellobium dulce	—	—	0.3	0.2	1.4	0.9	0.6	0.3
Thunbergia grandiflora	—	—	1.4	1.4	—	—	0.5	0.5
Mimosa diplotricha	0.2	0.2	—	—	1.3	0.9	0.5	0.3
Amaranthus spinosus	0.1	0.1	1.1	1.1	—	—	0.4	0.4
Acacia confusa	—	—	0.1	0.1	0.9	0.9	0.4	0.3
Achyranthes aspera	—	—	0.3	0.3	0.6	0.4	0.3	0.2
Syngonium angustatum	—	—	0.8	0.8	—	—	0.3	0.3
Momordica charantia	0.4	0.3	0.3	0.3	0.3	0.1	0.3	0.1
Mucuna pruriens	—	—	0.2	0.2	—	—	0.1	0.1
Stachytarpheta jamaicensis	—	—	0.1	0.0	—	—	0.0	0.0
Tradescantia spathacea	—	—	0.0	0.0	—	—	0.0	0.0
Euphorbia cyathophora	0.0	0.0	—	—	—	—	0.0	0.0
Pennisetum polystachion	—	—	—	—	—	—	—	—

— = not observed.

disease, but both suppression from vines and human disturbance increased. Disturbance from livestock was unchanged, and there were no observations of other animal damage, including that of wild pigs. Pig damage is extensive on Guam, the largest island in the Mariana Islands chain, but it seems likely that it is limited in the CNMI by the rugged limestone terrain in most areas.

Invasive species are a significant threat to native forests in the Mariana Islands, and in 2015, invasive plants covered more than half of forest area in the CNMI. The tree *Leucaena leucocephala* (tångantångan) was the most widespread invasive species, covering as much forest area as the next 12 invasive plant species combined. However, on Rota, it covered less than 1 percent of forest area. The next most common invasive plant species, *Mikania micrantha* (mile-a-minute vine), covered six times less forest area than *L. leucocephala*. Of the 28 invasive species inventoried, 18 covered 1 percent or less of forest area. Among specific Pacific Island damage types that FIA field crews were trained

Figure 21—*Leucaena leucocephala* (tångantångan) forest on the island of Tinian, Commonwealth of the Northern Mariana Islands. USDA Forest Service photo by Matthew O'Driscoll.

to identify and record, only *Phellinus noxius* (brown root rot) was observed, and only on one tree. Guam has infestations of the invasive cycad scale, *Aulacaspis yasumatsui* (Takagi), and given the relatively healthy forests on Rota, there is considerable interest in the cycad and cycad infestation there. However, no cycads were measured in the CNMI inventories. The invasive coconut rhinoceros beetle, *Oryctes rhinoceros*, causes serious damage to coconut trees on Guam, but that damage was not observed in the CNMI.

About one-fifth of the CNMI's forest area had live canopy coverage of 50 percent or less, and more than half of plots were in partial forest. This suggests the forests in CNMI are patchy and fragmented, probably because of high levels of disturbance. About 20 percent of forest area was covered in shrubs, and another 11 percent was covered in grass, which describes a relatively low and open structure for a tropical forest. However, mean stem density of trees was very high at almost 1,400 stems per acre. Many of these were stems of the invasive tree, *L. leucocephala,* which grows closely together and in 2015 composed 43 percent of all trees, 31 percent of all basal area, and 25 percent of forest area in the CNMI. While *L. leucocephala* dominated the forested landscape on Saipan and especially Tinian, native/endemic trees made up most of the CNMI's forest structure overall.

As with the 2004 FIA inventory, smaller size trees characterized the CNMI's forests in 2015. About 11 percent of trees grew from the 1.0–2.9-inch DBH size class to the 3.0–4.9-inch DBH size class, and there was a significant increase in mean basal area per acre. Most trees in 2015 were still less than 3 inches DBH and less than 25 feet tall. Tree damage overall in 2015 was almost double that in 2004. This may have been due to a new measurement protocol for recording any visual evidence of stem decay as there were no observations of tree disease in 2004, but over half of all trees were coded with stem disease in 2015.

There was a statistically insignificant increase in tree abundance between inventories, but four of five of the most salient changes by tree species were net losses. Despite being the most abundant tree, *L. leucocephala*

gained and lost about equal numbers of trees between inventories, which resulted in an inconclusive net change in abundance. This could be attributed to it being a short-lived, early-successional species with shrub-like growth, with stems growing quickly, being easily damaged and quickly rotting away, and being replaced by other stems from the same root systems. As such, the massive growth and mortality in *L. leucocephala* may indicate cycling of stems rather than changes in entire trees. *Pandanus dubius* (påhong) had a relatively low level of damage but experienced the largest loss of trees to mortality compared to its relative abundance and dominance among all species. It also had the largest biomass loss by species between inventories.

Leucaena leucocephala had by far the largest net gain in biomass, along with the largest loss of biomass to mortality and the only significant loss to removals among all species inventoried. Its net gain was more than 10 times greater than almost all species with significant net changes in biomass. Biomass overall increased between inventories, with an annual net increase of about 2.1 percent.

Tree species richness per plot was relatively low for Micronesia, which was partly due to 19 percent of plots having only one species, *L. leucocephala*, present. Dominant vascular plant richness, however, was relatively high. This may be due to many dominant invasive plant species in the forest understory. For the top 20 most dominant tree species, only 1 was invasive and 3 were endemic; but for the top 20 dominant nontree plant species, 9 were invasive and only 1 was endemic to the Mariana Islands. The rate of endemism among trees in the CNMI was high with 18 percent endemic to Micronesia and 16 percent endemic to the Mariana Islands. The Mariana Islands endemics *Guamia mariannae* (paipai) and *Maytenus thompsonii* (luluhut) appear to play important roles in CNMI forests as they are both in the top five most common tree species, top twenty most dominant tree species, and top ten most dominant seedling/sapling species.

Forests in the CNMI provide a wide range of ecosystem services beneficial to human beings and other organisms, such as protection and creation of soil; provision of clean, fresh water; regulation of temperature; and production of food, medicine, and building materials (CNMI SWARS 2015). However, along with Guam, CNMI forests have the smallest trees, lowest basal area, highest stem density, lowest average canopy cover, and highest levels of disturbance and invasive species coverage in Micronesia (Dendy et al. 2020). Ongoing monitoring of forests in the CNMI through programs such as FIA are important for summarizing the general status and trends of forest health. This information can be used to inform CNMI residents of issues threatening native species and gives resource managers the data needed to focus their limited time, effort, and finances on protecting the healthiest forest areas, such as those on Rota; protecting and restoring forests surrounding the most crucial freshwater resources for the largest urban areas, such as those on Saipan; and restoring the most disturbed forest areas, such as those on Tinian.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	0.3048	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	0.405	Hectares
Square feet (ft^2)	0.0929	Square meters
Cubic feet (ft^3)	0.0283	Cubic meters
Tons (ton)	0.907	Tonnes or megagrams
Trees per acre	2.47	Trees per hectare
Degrees Fahrenheit (°F)	0.56(°F – 32)	Degrees Celsius

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APPENDIX 1
Scientific and Common Names of Plants Found During Inventory

Life form	Scientific name	Authority	Chamorro common name
Trees	*Acacia confusa*	Merr.	Sosugi
Trees	*Adenanthera pavonina*	L.	Kulalis
Trees	*Aglaia mariannensis*	Merr.	Mapunyao
Trees	*Aidia cochinchinensis*	Lour.	Sumak
Trees	*Albizia lebbeck*	(L.) Benth.	Trongkon kalaskas
Trees	*Annona muricata*	L.	Laguanå
Trees	*Annona squamosa*	L.	Ates
Trees	*Areca catechu*	L.	Pu-gwa'
Trees	*Artocarpus altilis*	(Parkinson) Fosberg	Lemai
Trees	*Artocarpus mariannensis*	Trécul	Dogduk
Trees	*Bixa orellana*	L.	Lipsticktree
Trees	*Carica papaya*	L.	Papåya
Trees	*Casuarina equisetifolia*	L.	Gågu
Trees	*Citrus medica*	L.	Rough lemon
Trees	*Cocos nucifera*	L.	Niyog
Trees	*Cynometra ramiflora*	L.	Gulos
Trees	*Delonix regia*	(Bojer ex Hook.) Raf.	Atbut
Trees	*Dendrocnide latifolia*	(Gaudich.) Chew	Katot
Trees	*Drypetes dolichocarpa*	Kaneh.	Mwelel
Trees	*Drypetes* sp.	Vahl	

Life form	Scientific name	Authority	Chamorro common name
Trees	*Elaeocarpus joga*	Merr.	Yoga
Trees	*Eugenia palumbis*	Merr.	Agatelang
Trees	*Eugenia reinwardtiana*	(Blume) A.Cunn. ex DC.	A'abang
Trees	*Excoecaria agallocha*	L.	Blinding tree
Trees	*Ficus prolixa*	G. Forst.	Nunu
Trees	*Ficus tinctoria*	G. Forst.	Hodda
Trees	*Geniostoma rupestre*	J.R. Forst. & G. Forst.	Målok håyu
Trees	*Guamia mariannae*	(Saff.) Merr.	Paipai
Trees	*Guettarda speciosa*	L.	Panao
Trees	*Hernandia labyrinthica*	Tuyama	Oschal
Trees	*Hernandia sonora*	L.	Oschal
Trees	*Hibiscus tiliaceus*	L.	Pågo
Trees	*Intsia bijuga*	(Colebr.) Kuntze	Ifit
Trees	*Leucaena leucocephala*	(Lam.) de Wit	Tångantångan
Trees	*Mammea odorata*	(Raf.) Kosterm.	Chopak
Trees	*Maytenus thompsonii*	(Merr.) Fosberg	Luluhut
Trees	*Melanolepis multiglandulosa*	(Reinw. ex Blume) Rchb. f. & Zoll.	Ålum
Trees	*Morinda citrifolia*	L.	Lada
Trees	*Neisosperma oppositifolia*	(Lam.) Fosberg & Sachet	Fagot
Trees	*Ochrosia mariannensis*	A. DC.	Langiti
Trees	*Pandanus dubius*	Spreng.	Påhong
Trees	*Pandanus tectorius*	Parkinson ex Du Roi	Kaffo'
Trees	*Pemphis acidula*	J.R. Forst. & G. Forst.	Nigas
Trees	*Pipturus argenteus*	(G. Forst.) Wedd.	Amahåyan
Trees	*Pisonia grandis*	R. Br.	Umumu
Trees	*Pisonia umbellifera*	(J.R. Forst. & G. Forst.) Seem.	Birdlime tree
Trees	*Pithecellobium dulce*	(Roxb.) Benth.	Kamachile
Trees	*Polyscias grandifolia*	Volkens	Pepega
Trees	*Pouteria obovata*	(R. Br.) Baehni	Lalaha
Trees	*Premna obtusifolia*	R. Br.	Åhgao
Trees	*Psychotria mariana*	Bartl. ex DC.	Aploghating
Trees	*Scaevola taccada*	(Gaertn.) Roxb.	Nanåso
Trees	*Spathodea campanulata*	P. Beauv.	Apär
Trees	*Tarenna sambucina*	(G. Forst.) Durand	Walmwasching
Trees	*Veitchia merrillii*	Becc.	Manila palm
Forbs	*Abrus precatorius*	L.	Rosarypea
Forbs	*Achyranthes aspera*	L.	Devil's horsewhip
Forbs	*Antigonon leptopus*	Hook. & Arn.	Chain of love
Forbs	*Bidens alba*	(L.) DC.	Romerillo
Forbs	*Blechum pyramidatum*	(Lam.) Urb.	Browne's blechum
Forbs	*Capsicum annuum* var. *glabriusculum*	(Dunal) Heiser & Pickersgill	Cayenne pepper
Forbs	*Cassytha filiformis*	L.	Devil's gut
Forbs	*Centrosema molle*	Mart. ex Benth.	Centro

Life form	Scientific name	Authority	Chamorro common name
Forbs	*Chromolaena odorata*	(L.) R.M. King & H. Rob.	Masigsig
Forbs	*Commelina benghalensis*	L.	Jio
Forbs	*Coccinia grandis*	(L.) Voigt	Ivy gourd
Forbs	*Colocasia esculenta*	(L.) Schott	Coco yam
Forbs	*Davallia heterophylla*	Sm.	Haresfoot fern
Forbs	*Davallia solida*	(J.R. Forst.) Sw.	
Forbs	*Dicranopteris linearis*	(Burm.) Underw.	Old World forkedfern
Forbs	*Elephantopus mollis*	Kunth	Soft elephantsfoot
Forbs	*Epipremnum pinnatum*	(L.) Engl.	Pothos
Forbs	*Euphorbia cyathophora*	Murray	Fire on the mountain
Forbs	*Flagellaria indica*	L.	
Forbs	*Ipomoea indica*	(Burm. f.) Merr.	Oceanblue morning-glory
Forbs	*Ipomoea triloba*	L.	Littlebell
Forbs	*Microsporum punctatum*	(L.) Copel.	Climbing birdsnest fern
Forbs	*Mikania micrantha*	Kunth	Mile-a-minute vine
Forbs	*Momordica charantia*	L.	Bitter melon
Forbs	*Mucuna gigantea*	(Willd.) DC.	Seabean
Forbs	*Mucuna platyphylla*	A. Gray	
Forbs	*Mucuna pruriens*	(L.) DC.	Akangkang dangkulo
Forbs	*Musa balbisiana*	Colla	Banana
Forbs	*Nephrolepis biserrata*	(Sw.) Schott	Giant swordfern
Forbs	*Nephrolepis hirsutula*	(J.R. Forst.) C. Presl	Scaly swordfern
Forbs	*Operculina turpethum* var. *ventricosa*	(Bertero) Austin & Staples	Paper rose
Forbs	*Pachyrhizus erosus*	(L.) Urb.	Yam bean
Forbs	*Passiflora foetida*	L.	Fetid passionflower
Forbs	*Passiflora suberosa*	L.	Corkystem passionflower
Forbs	*Phymatosorus scolopendria*	(Burm. f.) Pic. Serm.	Monarch fern
Forbs	*Piper betel*	L.	Betel pepper
Forbs	*Plumbago zeylanica*	L.	Wild leadwort
Forbs	*Pyrrosia lanceolata*	(L.) Farw.	
Forbs	*Ruellia prostrata*	Poir.	Prostrate wild petunia
Forbs	*Sansevieria trifasciata*	hort. ex Prain	Viper's bowstring hemp
Forbs	*Stachytarpheta urticifolia*	Sims	Nettleleaf velvetberry
Forbs	*Stachytarpheta jamaicensis*	(L.) Vahl	Light-blue snakeweed
Forbs	*Stictocardia* sp.	Hallier f.	Stictocardia
Forbs	*Stictocardia tiliifolia*	(Desr.) Hallier f.	Spottedheart
Forbs	*Syngonium angustatum*	Schott	Fivefingers
Forbs	*Tradescantia spathacea*	Sw.	Boatlily
Forbs	*Tectaria crenata*	Cav.	
Forbs	*Thelypteris opulenta*	(Kaulf.) Fosberg	Jeweled maiden fern
Forbs	*Thunbergia grandiflora*	Roxb.	Blue trumpetvine
Graminoids	*Bambusa vulgaris*	Schrad. ex J.C. Wendl.	Bamboo
Graminoids	*Cyperus polystachyos* var. *polystachyos*	Rottb.	Manyspike flatsedge

Life form	Scientific name	Authority	Chamorro common name
Graminoids	*Digitaria setigera*	Roth ex Roem. & Schult.	East Indian crabgrass
Graminoids	*Eleusine indica*	(L.) Gaertn.	Indian goosegrass
Graminoids	*Eustachys petraea*	(Sw.) Desv.	Pinewoods fingergrass
Graminoids	*Lepturus repens*	(G. Forst.) R. Br.	Pacific Island thintail
Graminoids	*Miscanthus floridulus*	(Labill.) Warb. ex K. Schum. & Lauterb.	Pacific Island silvergrass
Graminoids	*Oplismenus compositus*	(L.) P. Beauv.	Running mountaingrass
Graminoids	*Oplismenus hirtellus*	(L.) P. Beauv.	Basketgrass
Graminoids	*Paspalum paniculatum*	L.	Arrocillo
Graminoids	*Pennisetum polystachion*	(L.) Schult.	Mission grass
Graminoids	*Pennisetum purpureum*	Schumach.	Elephant grass
Graminoids	*Urochloa maxima*	(Jacq.) R. Webster	Guinea grass
Shrubs	*Alyxia stellata*	(J.R. Forst. & G. Forst.) Roem. & Schult.	
Shrubs	*Amaranthus spinosus*	L.	Spiny amaranth
Shrubs	*Bikkia tetrandra*	(L.f.) A. Rich.	Gausåli
Shrubs	*Bougainvillea spectabilis*	Willd.	Great bougainvillea
Shrubs	*Capsicum annuum* var. *glabriusculum*	(Dunal) Heiser & Pickersgill	Cayenne pepper
Shrubs	*Canavalia megalantha*	Merr.	
Shrubs	*Clerodendrum inerme*	(L.) Gaertn.	Embrert
Shrubs	*Codiaeum variegatum*	(L.) A. Juss.	Garden croton
Shrubs	*Colubrina asiatica*	(L.) Brongn.	Asian nakedwood
Shrubs	*Deeringia amaranthoides*	(Lam.) Merr.	
Shrubs	*Desmodium gangeticum*	(L.) DC.	
Shrubs	*Discocalyx megacarpa*	Merr.	Otot
Shrubs	*Flagellaria indica*	L.	
Shrubs	*Freycinetia reineckei*	Warb.	
Shrubs	*Jasminum marianum*	DC.	Banago
Shrubs	*Lantana camara*	L.	Lantana
Shrubs	*Maesa walkeri*	Fosberg & Sachet	
Shrubs	*Manihot esculenta*	Crantz	Cassava
Shrubs	*Mimosa diplotricha*	C. Wright	Giant false sensitive plant
Shrubs	*Morinda umbellata*	auct. non L.	Redgal
Shrubs	*Mucuna gigantea*	(Willd.) DC.	Seabean
Shrubs	*Rivina humilis*	L.	Rougeplant
Shrubs	*Triphasia trifolia*	(Burm. f.) P. Wilson	Limon di china
Shrubs	*Wikstroemia elliptica*	Merr.	

Sources: Trees: Falanruw et al. (1990), Raulerson and Rinehart (2021); forbs, graminoids and shrubs: USDA (n.d.).

APPENDIX 2

Sample Error/Other Error

We report sample error (SE) of the mean for every estimate in this report, and it is crucial for assessing reliability of the estimate. The smaller the SE value is compared to the estimate, the more reliable the estimate is.

The value of SE added to and subtracted from the estimate creates a range (low value to high value) of confidence in which the true value of the population is likely to occur. If we repeatedly sampled the population and constructed a confidence interval in such a way, the true value would be within these confidence intervals about 68 percent of repeats. An about 95-percent confidence level interval can be created by multiplying the SE by 2 (and adding to and subtracting from the estimate). SE can be used to create intervals with any confidence level, as needed, using a statistical reference table (t table).

The U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis program follows a strict protocol to ensure the high quality of data collected, including quality assurance and control procedures for measurements, data entry, and processing. However, measurement errors; species misidentifications; and mistakes in data entry, processing, and analysis still occur, although the program makes considerable effort to minimize them. We presented data with the precision of one decimal point, which in some cases results in totals not summing to exactly 100 percent.

Glossary

biodiversity—Variety and variability among living organisms and the ecological complexes in which they occur. Biodiversity can include genetic, species, and ecosystem diversity, including the number of different items and their relative frequencies (Glowka et al. 1994).

biomass—The aboveground weight of wood and bark in live trees that are ≥1 inch diameter at breast height, from the ground to the tip of the tree, excluding all foliage. The weight of wood and bark in lateral limbs, secondary limbs, and twigs under 0.5 inch in diameter at the point of occurrence on sapling-size trees is included.

condition class—The combination of discrete landscape and forest attributes that identify, define, and stratify the area associated with a plot. Such attributes include reserved status, owner group, forest type, stand-size class, stand origin, and tree density.

damage—Damage to trees caused by biotic agents such as insects, diseases, and animals or abiotic agents such as weather, fire, or mechanical equipment.

diameter at breast height (DBH)—The diameter of a tree stem, located 4.5 ft (1.37 m) above the ground ("breast height") on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees (USDA FS 2016).

disturbance—Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment (Helms 1998).

ecosystem—A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and components of the abiotic environment within its boundaries. An ecosystem can be of any size: a log, a pond, a field, a forest, or the Earth's biosphere (Helms 1998).

endemic—Plant species that are unique to a defined geographical location, e.g., species only found in the Mariana Islands.

forb—A broad-leaved herbaceous plant, as distinguished from grasses, shrubs, and trees (USDA FS 2016).

forest community—A classification of forest land based on and named for the tree species that forms the plurality of live-tree cover that is not overtopped, delineated by the classification guide outlined in Mueller-Dombois and Fosberg (1998).

forest land—The USDA Forest Service Forest Inventory and Analysis program defines forest land as an area currently or formerly (within 30 years) exhibiting at least 10 percent crown cover of trees of any size and is not currently developed for nonforest use (USDA FS 2016). Forest land must occupy at least 1 acre and have a minimum continuous width of 120 feet.

grassland—Land on which the vegetation is dominated by grasses, grass-like plants, or forbs.

introduced species—species that are nonnative or naturalized and are introduced by humans and have established or expanded their populations (Balick and Kitalong 2020).

invasive species—Species that are nonnative to the ecosystem under consideration and that cause or are likely to cause economic or environmental harm or harm to human, animal, or plant health.

live trees—All living trees, including all size classes, all tree classes, and both commercial and noncommercial species listed in the USDA Forest Service Forest Inventory and Analysis field manual (USDA FS 2016).

mortality—The death of trees from natural causes or following incidents such as storms, wildfire, or insect and disease epidemics (Helms 1998).

native species—Plant species that were native to a region prior to Euro-American settlement.

remote sensing—Capture of information about the Earth from a distant vantage point. The term is often associated with satellite imagery but also applies to aerial photography, airborne digital sensors, ground-based detectors, and other devices.

sample error—Difference between a population value and a sample estimate that is attributable to the sample, as distinct from errors due to bias in estimation, errors in observation, etc. Sample error is measured as the standard error of the sample estimate (Helms 1998).

sapling—A live tree 1–4.9 inches in diameter at breast height (USDA FS 2016).

seedlings—Live trees <1-inch diameter at breast height and ≥12 inches in height (USDA FS 2016).

shrub—Perennial, multistem woody plant, usually <16 feet in height, although under certain environmental conditions shrubs may be single-stem or >16 feet in height. Includes succulents (e.g., cacti) and woody vines.

snag—A standing dead tree. To qualify as a snag, dead trees must be at least 1 inch diameter at breast height, have a bole that has an unbroken actual length of at least 4.5 feet, and have a lean angle that is less than 45 degrees from vertical.

stand-size class—A classification of stands based on tree size. Most trees in large-diameter stands are ≥11 inches diameter at breast height (DBH). Most trees in medium-diameter stands are ≥5 inches DBH but not as large as large-diameter trees. Most trees in small-diameter stands are <5 inches DBH.

succession—The gradual supplanting of one community of plants by another (Helms 1998).

tree—The USDA Forest Service Forest Inventory and Analysis (FIA) program defines a tree as a woody perennial plant, usually with a single, well-defined stem supporting a crown of leaves, with a minimum diameter at breast height of 3 inches (7.6 cm) and a minimum height of 15 feet (4.6 m) at maturity. Tally trees are defined as all live and standing dead trees (i.e., snags) in accessible forest land or measurable nonforest land condition classes (USDA FS 2016). Any plant species on FIA's tree list in the current field manual is measured as a tree.

understory—Lowermost canopy layer including shrubs, vines, and herbaceous vegetation, such as forbs and graminoids.

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