Micronesica 2020-01: 1–10

Growth and Stand Density of Honduran Mahogany on Guam[1]

ROBERT F. BEVACQUA
Agriculture and Life Science Division, College of Natural and Applied Sciences,
University of Guam, UOG Station, Mangilao, Guam 96923

MARIA LYNN CRUZ*
War in the Pacific National Historical Park
U.S. National Park Service
Hagatna, Guam 96910
marialynn_cruz@nps.gov

Abstract— A survey of a Honduran or big-leaf mahogany forest (*Swietenia macrophylla* King) was carried out in 2018-2019 at Piti on Guam. Results indicate the forest includes 516 mature trees that cover an area of 3.4 ha. The oldest trees are 92 years old. The average tree has a diameter at breast height (DBH) of 60.8 cm and a height of 17.7 m. The density is 152 trees/ha and the growth rate is 0.72 cm/year. The forest can be characterized by abundant natural regeneration (77,500 seedlings/ha), vigorous and constant growth and an absence of insect pests and plant diseases. A comparison with an earlier survey in 1992 indicates the forest has rapidly expanded, from 1.3 ha in 1992 to 3.4 ha in 2018.

Introduction

Guam's original mahogany planting is located at Piti Guns, a unit of War in the Pacific National Historical Park that features three WWII Japanese coastal defense guns (Fig. 1). The guns are accessed by a trail that begins at the Piti Village church and ascends through a hillside forest where the dominant tree is mahogany (*Swietenia macrophylla* King). These towering trees with a highly-desired wood form a forest that is rarely observed on Guam. These trees are the Honduran or big-leaf species of mahogany (Thompson et al. 2018). It is a commercially important timber tree prized for the beauty, durability, and color of its wood. The Honduran trees can be distinguished by their unique seed pods, relatively large leaves, rapid growth, and erect and straight growth habit.

The goal of this study was to compile information on the mahogany trees that can be used in interpretive programs to enhance the visitor's experience at Piti Guns.

The specfic objectives were to:

1. document the history of the mahogany trees;
2. prepare a map showing the extent of the forest;
3. conduct a survey of a sample of trees to determine diameter, height, and vigor; and
4. assess threats to the forest.

[1] Citation: Bevacqua, R.F. & M.L. Cruz. 2020. Growth and Stand Density of Honduran Mahogany on Guam, *Micronesica* 2020-01, 10 pp. Published online 31 December 2020. http://micronesica.org/volumes/2020

* Corresponding Author

Environmental Setting

Guam has a tropical climate that is uniformly warm and humid throughout the year. There are two distinct seasons. A dry season between December and May and a wet season from June to November. The mean annual rainfall, temperature, and humidity is 229 cm, 27°C, and 81%, respectively (U.S. Army Corps of Engineers, 1981). The soil on the Piti hillside is a thin clay over weathered limestone formations. The terrain is sloping and well-drained with an elevation that ranges from 12 m to104 m above sea level (Yoshioka, 2008).

Historical Background

To improve island food production, the U.S. government operated an agricultural experiment station in the village of Piti from 1909 to 1932 (Jennison-Nolan 1979, NPS 2013). The first mention of mahogany as a plant introduction for Guam is in a report for the experiment station for 1917 (GAES 1917). At that time, the dominant native hardwood, ifit (*Intsia bijuga*) was in decline and mahogany was being considered as a replacement. Ifit continues to be in decline because of overharvesting, land clearing, introduced insect pests, and seedling browsing by feral pig (*Sus scrofa*) and deer (*Cervus mariannus*) (Thaman et al. 2006). The first mahogany species to be introduced as an ifit replacement was the West Indian or Cuban mahogany (*Swietenia mahogani*). The source of the seed was the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry, USDA (GAES 1917). Later efforts switched to the Honduran type, *S. macrophylla* , which was becoming the more commercially important species in international trade. Trial plantings of the Honduran species showed great promise. This led to the planting of 208 seedlings in October of 1928 on the hillside above Piti (Jennison-Nolan 1979, NPS 2013). The young trees thrived in the island environment and developed into the grove that now surrounds the three big guns at Piti.

Palau shares a similar history in the introduction of mahogany. Plantations were established during the Japanese occupation in the 1930's (FAO 2000). Most of these original plantings have already been harvested. A tree planting program was started in 1970. Currently the Forestry Section is planting 10,000 seedlings per year. Mahogany is valued as a source of timber for furniture, story boards, and general use. At present there are many small plantations and some larger ones over 40 ha (Kitalong 2010).

On Guam in 1992, sixty-four years after planting, a survey of the mahogany trees (Jurgensen 1992) recorded 185 mature trees that covered an area of 1.3 ha (Fig. 1). A mature tree is one with a diameter at breast height (DBH) of 30 cm or larger. Some of the trees were over 30 m tall. Many formed a dense crown canopy. A large number of seedlings were observed on the forest floor. In her conclusion, Jurgensen (1992) remarked on the beauty, size, and near-pristine condition of the mahogany forest at Piti Guns. She also remarked that mahogany has been introduced on other Pacific Islands, but other than Palau, few have attained the success that is evident at Piti Guns on Guam.

Materials and Methods

The survey of mahogany trees at Piti Guns in 2018 was completed in six steps. 1) On June 13, 2018, an exploratory visit was conducted to refine the goals for the project. 2) On June 27, 2018, the perimeter and area of the current forest was established using hand-held compasses with the 1992 survey map used as a base. 3) On July 13, 2018, a 0.21 ha sample area was demarcated in the central area of the grove (Fig. 2) using hand-held compasses and measuring devices. The goal in laying out the sample area was to include trees from the original 1928 planting. 4) On July 26, 2018, measurements were recorded on the mature trees within the sample area. The methodology was the same as used in Jurgensen (1992). Mature trees were those with a diameter of 30 cm or greater. Diameter (DBH) was measured at breast height with a standard tape measure. Height was visually estimated. Vigor was used to describe the overall condition of a tree on a qualitative scale of high, medium, or low. Vigor describes the health and resilience of a tree. It reflects the capacity of a tree

to grow while withstanding stress (Wilson, 2015). The measurements recorded in this sample area were extrapolated to estimate the number of mature trees in the forest. A search was made for tags resulting from Jurgensen (1992) and the number recorded. Other characteristics were noted, such as the presence of storm damage. This was a visual estimate of the presence or absence of a canopy or whether the trunks were broken. A modern advancement in methodology from the 1992 survey was the use of hand-held GPS units (Garmin GPSmap 78 and 78sc units) to locate the position of the trees. 5) Lastly, a numbered aluminum tag was nailed into the trunk at breast height on the north side of the tree.

Concurrent with the field survey, archival research was done to ascertain the early history of the trees. This was done with the guidance of a professional librarian on July 11 and 25, 2018 at Micronesian Area Research Center (MARC) at University of Guam.

The sixth step took place on December 4, 2019, with the focus of measuring natural regeneration and the height of five trees from the original planting in 1928. Natural regeneration was measured by recording the number and height of seedlings in four one-meter radius, circular plots (adapted from Burkhart et al, 2018). The procedure was to stand in a central location in the sample area and throw rocks with colored streamers in the four directions: north, south, east, and west. Where the rock landed was the center of the plot. A tape measure was used to measure a circle with a radius of one meter. The number and height of all seedlings inside the circle were recorded. The heights of the five trees known to be planted in 1928 and included in both the 1992 and 2018-2019 surveys were recorded with a clinometer (Suunto PM-5/360 PC OPTI). Three replicate measurements were done to account for individual variance in measurements by field biologists and the difficulty in measuring tall trees in a dense forest habitat. We used the mean of these as the value reported for the final measurement.

Results and Discussion

The results of the mahogany survey in 2018, conducted 90 years after the initial planting in 1928, found the grove had expanded to an area of 3.4 ha and contained an estimated 516 mature trees. This rapid expansion can be attributed to the protection of the trees as a unit of a national park, a diminishing threat of fire, a favorable climate and absence of pests and competing plants. The overall health of the forest is excellent as evidenced by the high vigor ratings.

Measurements were recorded for the 32 mature trees located within a 0.21 ha sample area. The results of this survey are presented in Table 1 and indicate a mean DBH of 60.7 cm and a mean height of 17.7 m. Estimates for basal area and wood volume are 46.4 m^2/ha and 827.6 m^3/ha. The distribution of the tree diameters is presented in Fig. 3.

There is a high level of natural regeneration. This is illustrated in the results of seedling counts in four small plots (Table 2) and the absence of any other tree seedlings. The mean number of seedlings/ha was 77,500. This natural regeneration can be compared to the number of trees required for planting a new forest. Typical densities for the planting of forest trees range from 1000 to 2500 trees/ha (Dandy 2020). The natural regeneration on Guam is 30 times higher than the number of seedlings that would be needed to plant a hectare.

Of special interest are the five trees in the sample area that were planted in 1928 (Table 3). Sixty-five years later, in the 1992 survey, these five trees have a mean DBH of 46.7 cm and a growth rate of 0.72 cm/year. Twenty-seven years later, in the second survey in 2018, these same trees had an average DBH of 66.3 cm and a growth rate of 0.73 cm/year. This is a remarkably steady or constant rate of growth over a 90 year period. Three of the five trees were rated as having high vigor with straight trunks and ample foilage. The remaining two had been physically damaged by storms.

The density of trees was calculated to be 142 trees/ha in 1992 and 152 trees/ha in 2018. These figures can be favorably compared to a recommended density of 100 trees/ha in commercial forests in Mexico (Snook and Negreros-Castillo 2004).

There are no eminent threats to the mahogany grove. The trees' good health is evidenced by their robust growth, high vigor scores (Table 1), and active natural regeneration. Thousands of seedlings can be observed on the forest floor (Table 2). The trees are also remarkably free of insect and disease damage.

A subtle threat confronts the oldest of the trees. As the trees advance in age and height, they become susceptible to wind damage by typhoons or other storms. Structural damage to the tops of older trees from storms was the most commonly recorded problem in our 2018 survey. Mahogany plantings can be harvested at 35 years of age (Thomson et al. 2018). At 92 years of age, the Piti trees are well beyond this harvestable stage. This may explain their increasing vulnerability to storm damage as they approach 30 m in height.

The trees appear well-able to withstand competition from invasive plant species. African tulip tree (*Spathodea campanulata*), tangentangen (*Leucaena leucocephala*), palma brava (*Heterospathe elata*), and various vines are present at Piti Guns, but they do not encroach into the mahogany stand. Feral pigs (*Sus scrofa*) root on the forest floor, but their presence does not appear to be negative. Lightning strikes could be considered possible threats. Fire damage was recorded in the 1992 survey, but the threat of fires is much diminished now. No fire damage was recorded in 2018.

Conclusions

In 1928, 208 mahogany seedlings were planted on the hillside above Piti. The planting has thrived and developed into a forest that now surrounds the historic guns. A survey in 1992 recorded 185 mature trees that covered an area of 1.3 ha. The present survey in 2018 found the grove had expanded to an area of 3.4 ha and included 516 mature trees. This represents a 2.7-fold increase in area in the 27 years since the 1992 survey. 'Vigorous' is the adjective that best describes the steady growth of the mahogany at Piti.

The overall health of the trees is excellent. The only threat of concern is that as the trees advance in age and height they become susceptible to wind damage during storms.

The towering beauty of the trees can serve to enhance the visitor experience at Piti Guns. Trails should be developed to incorporate the trees into the attraction of the historic guns.

Acknowledgements

We would first like to thank Artak Davtian and Michael Gawel of National Park Service for supervising this project. Next, we are grateful for field assistance from Donavan Nelson and Caleb White (Youth Conservation Corp.) and Hannah White (Pacific Historic Parks). Lourdes Nededog of the University of Guam Micronesian Area Research Center graciously contributed archival research on mahogany in Guam. We are also indebted to the Fall 2019 Introduction to Agriculture (AL-101) class at the University of Guam for field data collection. Finally, we thank the two reviewers, one anonymous and Adrian Ares, Associate Director of the Western Pacific Tropical Research Center, of this manuscript for their help and suggestions.

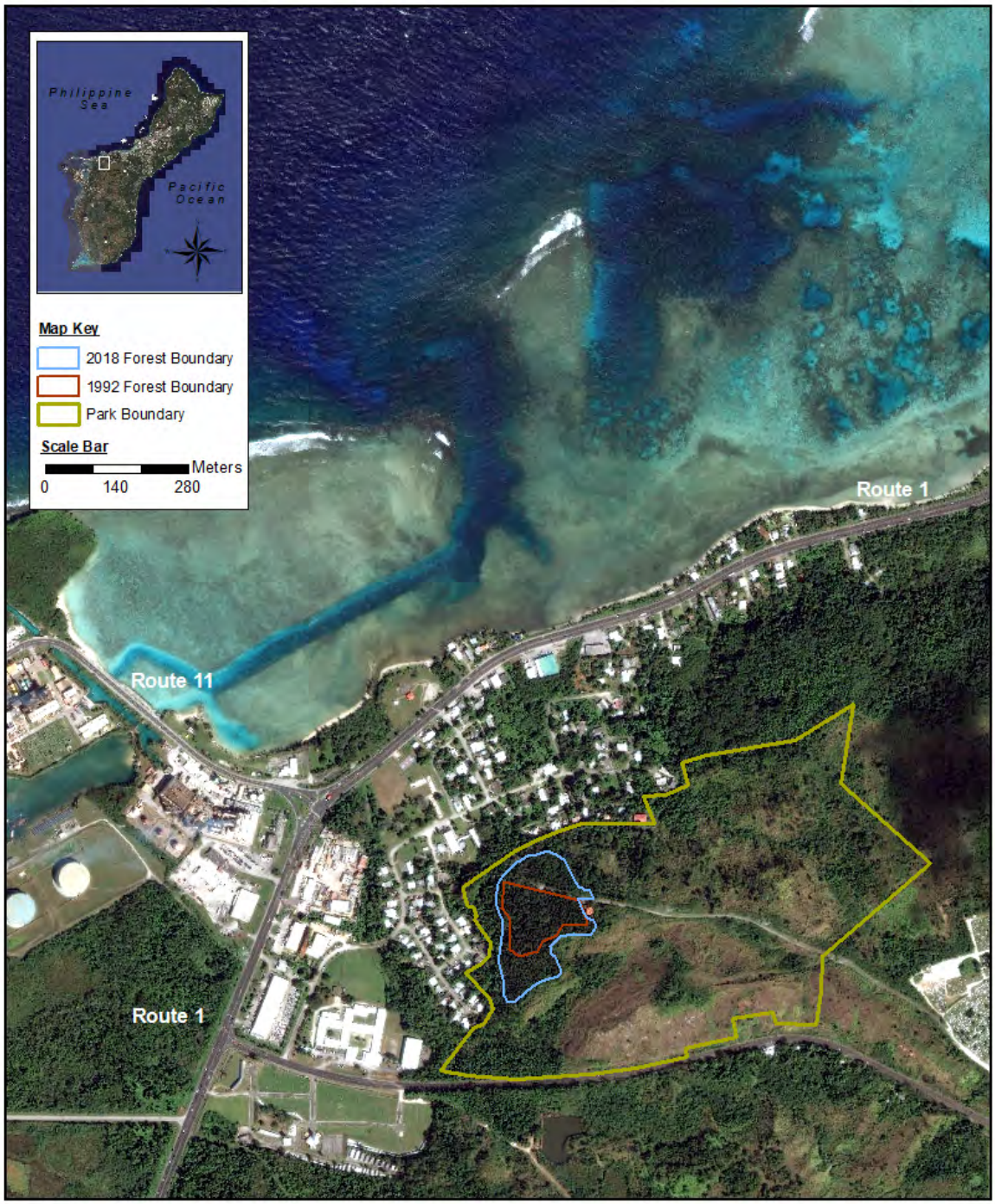

Figure 1. Map of Guam showing the location of the Piti Guns Unit of War in the Pacific National Historical Park. The unit boundary is marked in yellow. The boundaries for the mahogany grove are marked in red for 1992 and blue for 2018.

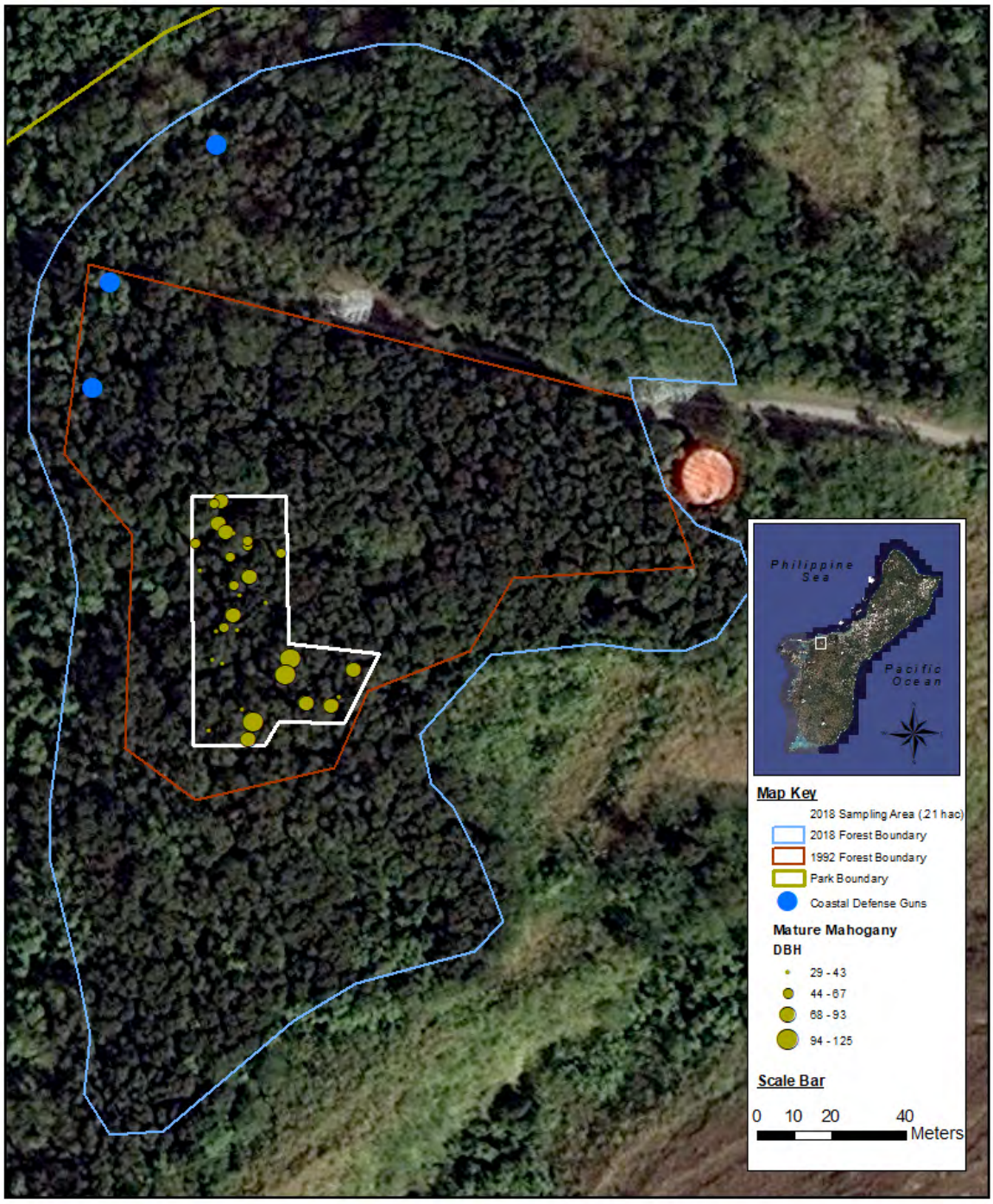

Figure 2. Map of Piti Guns Unit showing the location of the three coastal defense guns (blue), the perimeters of the mahogany forest in 1992 (red), in 2018 (blue), and the area sampled (white) in 2018-2019.

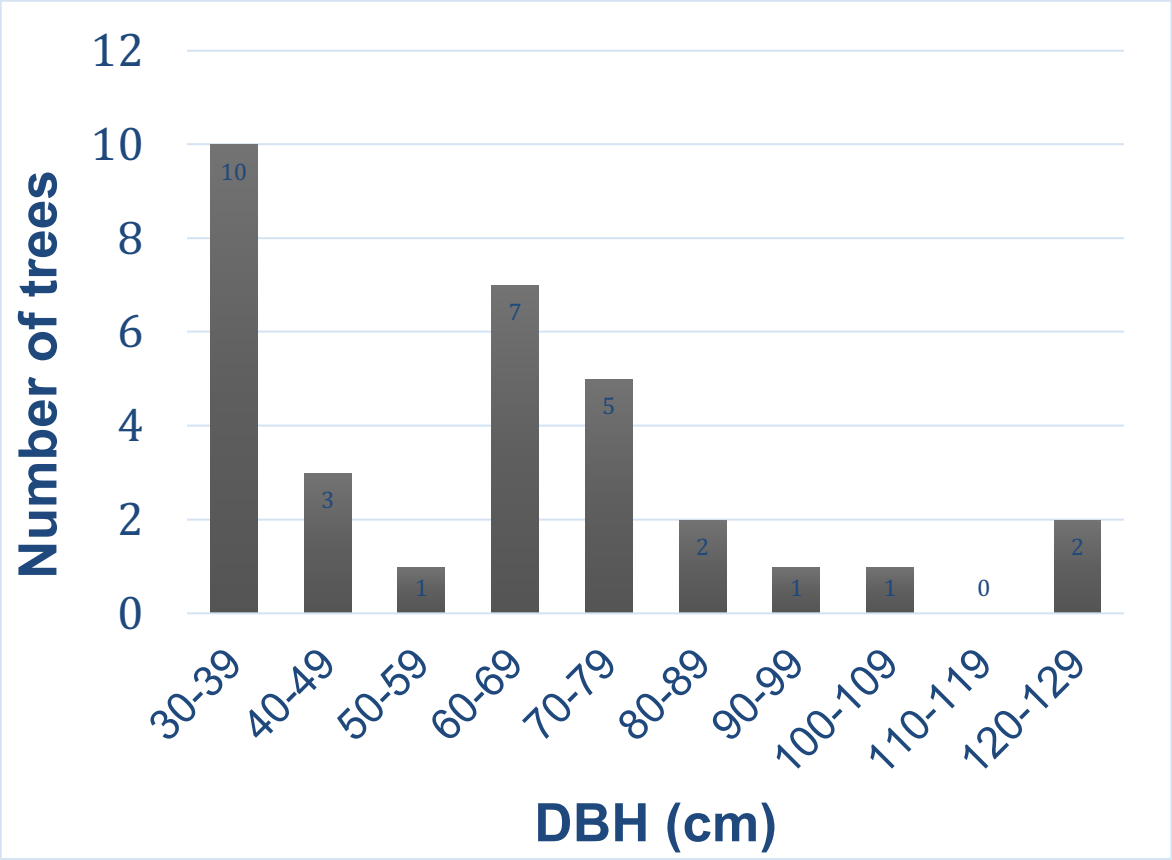

Figure 3. Diameter (DBH in cm) distribution of 32 mature mahogany trees in a sample area at Piti Guns Unit, 2018-2019.

Table 1. Results of a survey of 32 mature mahogany trees in a centrally located 0.21 hectare sample area at Piti Guns Unit, 2018.

Tree#	DBH (cm)	Ht (m)	Vigor	Remarks
281	72	12	M	
282	36	17	M	Burn scar
283	78	17	L	Storm damage
284	74	28	H	
285	93	28	M	
286	103	30	H	
287	33	23	M	Twin trunks
288	30	22	H	
289	32	18	M	Storm damage, no top
290	75	28	H	
291	32	33	L	
292	61	7	L	Storm damage
293	53	28	H	
294	62	28	H	
295	89	28	H	
296	66	11	M	Storm damage
297	32	7	L	Storm damage
298	86	27	H	
299	70	13	L	Storm damage
300	66	12	L	Storm damage
301	29	17	H	Twin trunks
302	65	16	H	
303	54	5	L	Storm damage, no top
304	67	3	L	Storm damage, no top
305	43	12	H	
306	47	7	L	Storm damage, no top
307	31	10	H	
308	36	10	H	
309	43	13	H	
310	31	13	H	
311	123	23	H	
312	125	20	H	

Table 2. Mahogany seedling number per m^2, per ha, and average height (cm) in four, circular, one-meter radius plots at Piti Guns Unit, 2019.

Plot Name	Seedlings/m^2	Seedlings/ha	Seedling Height (cm)
North	10	100,000	33.3
South	11	110,000	23.5
East	6	60,000	16.1
West	4	40,000	18.4
Average	**7.75**	**77,500**	**22.8**

Table 3. DBH, height, and vigor of five mahogany trees planted in 1928 and included in surveys in 1992 and 2018-2019.

Tag No. (1992/2019)	DBH (cm) (1992)	DBH (cm) (2019)	Height (m) (2019)	Vigor[1] (2019)	Remarks (2019)
755/293	36.0	53.4	28	H	straight trunk, ample foilage
796/296	54.0	65.5	11	M	storm damage, trunk broken
789/298	49.3	86.5	27	H	straight trunk, ample foilage
787/302	46.4	64.7	16	H	straight trunk, ample foilage
788/303	47.6	61.5	5	L	storm damage, no crown
Average:	**46.7**	**66.3**	**17.4**	**M-H**	

[1]Vigor was estimated as H for high, M for medium, and L for low.

References

Burkhart, H.E., Avery, T.E., and B.P. Bullock. 2018. Forest Measurements. Sixth Edition. Waveland Press, 434 p.

Dandy, S. 2020. NHS Forest. Centre for Sustainable Healthcare. United Kingdom: www.nhsforest.org

Food and Agriculture Organization. 2000. National Forest Programmes (NFP) Update 34: Palau. United Nations. (http://www.fao.org) accessed 16 June 2020.

Guam Agricultural Experiment Station. 1917. Report. Government Printing Office, Washington DC, pages 30-31.

Jennison-Nolan, J. 1979. Land and Lagoon Use in Prewar Guam: Agat, Piti, and Asan, pages 27-28. MARC Working Papers No. 15, University of Guam.

Jurgensen, L. K. 1992. Mensuration of a Sweitenia macrophylla grove, Guam. U.S. Forest Service, Honolulu, Hawaii (unpublished manuscript).

Kitalong, A.H. 2010. Republic of Palau Statewide Assessment of Forest Resources: A comprehensive analysis of forest related conditions, trends, threats and opportunities. Forestry Section, Koror.

Snook, L.K., Negreros-Castillo, P. 2004. Regenerating mahogany (Swietenia macrophylla King) on clearing in Mexico's Maya forest: the effects of clearing method and cleaning on seedling survival and growth . Forest Ecology and Management 189 :143-160. ISSN: 0378-1127.

Thaman, R.R., L.A.J. Thomson, R. DeMeo, R. Areki, and C.R. Elevitch. 2006. Intsia bijuga (vesi), ver. 3.1. In: Elevitch, C.R. (ed.). Species Profiles for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Hōlualoa, Hawai‘i. (http://www.traditionaltree.org) accessed 17 June 2020.

Thomson L., Doran J. and Clarke B. (eds) 2018. Trees for life in Oceania: Conservation and Utilisation of genetic diversity. ACIAR Monograph No. 201. Australian Centre for International Agricultural Research: Canberra.

U.S. Army Corps of Engineers. 1981. Asan Village Flood Control Study. Fort Shafter, Hawaii.

Wilson, P.J. 2015. A – Z of tree terms: a companion to British arboriculture. Ethelburga House, United Kingdom: www.treeterms.co.uk

Received 14 Mar. 2019, revised 04 Nov. 2020.