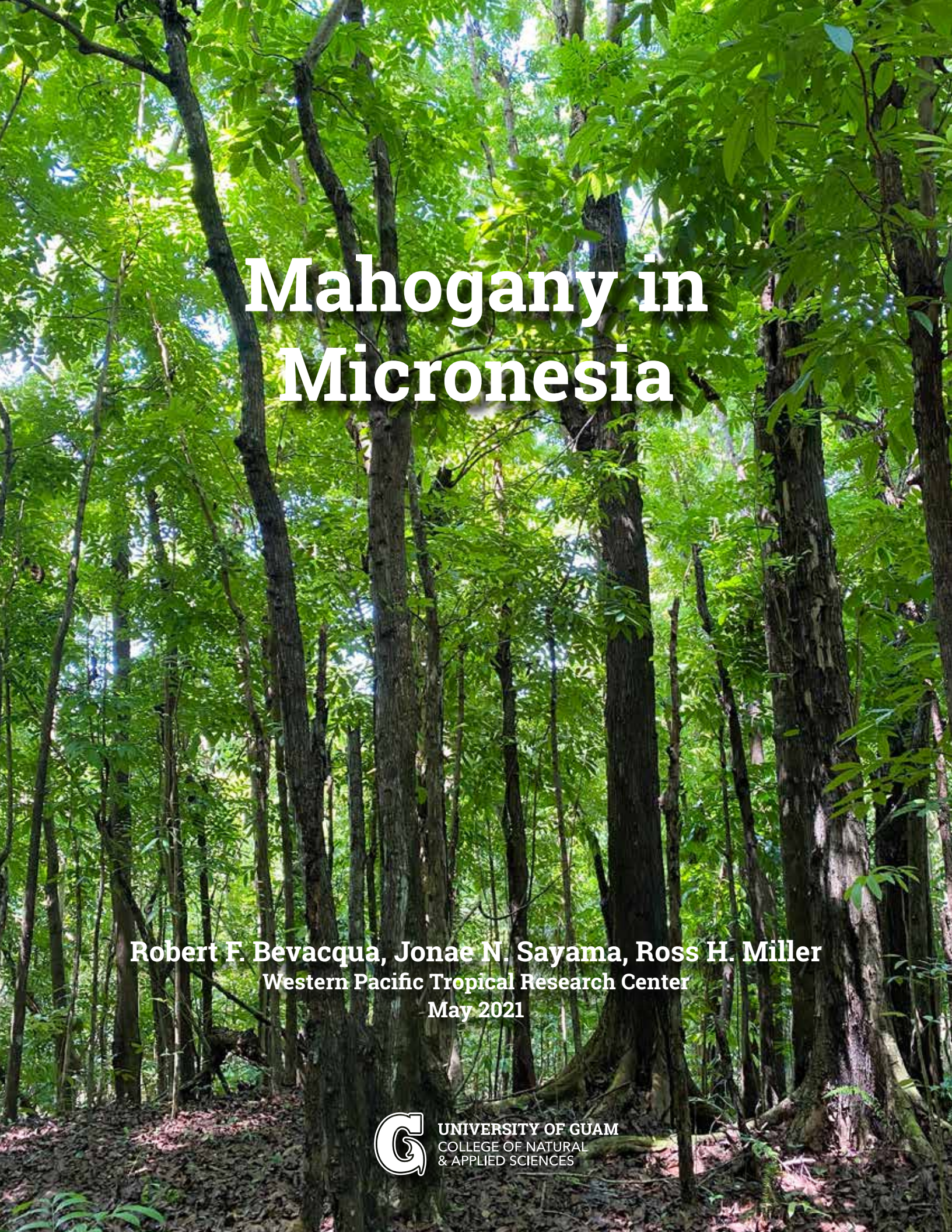

Mahogany in Micronesia

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Front cover. The success of Honduran mahogany plantings in Guam and Palau indicates the tree may be of value in the other islands of Micronesia.

Introduction

Mahogany (*Swietenia macrophylla* King) is one of the best-known and most valuable tropical trees in world commerce (Mayhew and Newton 1998). However, the potential for mahogany plantings in Micronesia has received little attention. The success of mahogany introductions on Guam (Figure 1) and in Palau indicates the species may be of value to the other islands in the Western Pacific. The development of small mahogany plantings could make significant contributions to the islands' desire for increasing self-sufficiency and sustainability. The main aim of this publication is to produce a guide, based largely on the authors' experience with mahogany on Guam, for the growing of this highly valued hardwood in Micronesia.

Figure 1. Author Robert Bevacqua stands beside a Honduran mahogany tree at Piti Guns on Guam that measures over 32 m in height.

Taxonomy

This publication focuses on the cultivation of Honduran big-leaf mahogany. It is scientifically known as *Swietenia macrophylla* and belongs to the botanical family of Meliaceae (Thomson *et al.* 2018). This commercially important species is referred to as true or genuine mahogany. There are many other tree species marketed as mahogany and this has lead to much confusion, but they are of lesser commercial value.

Origin and Distribution

The origin of Honduran mahogany lies in the tropical Americas (Krisnawati *et al*. 2011), but due to the high value of its timber, the species is now widely planted in the tropical regions of the Americas, Asia, Africa, and some Pacific Islands. Brazil and Peru have developed as centers of commercial production, but illegal logging and the related destructive environmental effects have led to some restrictions on the international trade of mahogany (US-FWS 2017). The principal importers are the United States and the United Kingdom.

In the Melanesian islands, successful mahogany plantations are established in Fiji, and, to a lesser extent, in the Solomon Islands and Papua New Guinea (Hammond 2002). In Micronesia mahogany is grown as a cottage industry in Palau and in trial plantings on Guam. These latter two areas will be explored more fully in later sections.

Environmental Setting

Mahogany can tolerate a wide range of climatic and soil conditions (Krisnawati *et al*. 2011). It grows best in humid and subhumid climates with a mean annual rainfall of 198-398 cm (Thomson *et al*. 2018). Whether the rainfall is distributed uniformly throughout the year or whether there is a distinct dry season is not a critical factor (Thomson *et al*. 2018). Mahogany is also adapted to a wide range of soil conditions (Krisnawati *et al*. 2011). On Guam, for example, the trees thrive in well-drained soils derived from limestone, as well as soils volcanic in origin.

Distinguishing Characteristics

Many features, in addition to its excellent timber quality, distinguish mahogany from other forest trees: erect and straight growth habit (Figure 2a), distinctive leaf arrangement (Figure 2b), unique fruit or seed capsules (Figure 2c), winged seeds, relatively large leaves (Figures 2b), rapid growth, and buttresses at the base of the trunk (Figure 2d).

Another interesting feature is that the trees can be briefly deciduous where, for a short period, all the leaves are shed (Figure 2e).

On Guam, a mahogany tree that is 92 years old, has achieved a height of 30 m and a diameter at breast height (DBH) of 51 cm (Bevacqua and Cruz 2020).

Figure 2a. Erect and straight growth.

Figure 2b. Leaf arrangement.

Figure 2c. Seed capsules.

Figure 2d. Buttresses.

Figure 2e. Shedding of leaves.

Uses as Wood

Mahogany produces attractive timber with good technical characteristics which have made it one of the world's most valuable and best-known woods (Figure 3) for furniture (Thomson *et al*. 2018). While it is principally used for furniture and cabinets, it is suited to a wide range of uses, including wood carvings, veneers, doors, boat-building, musical instruments, firewood, and construction materials (Thomson *et al*. 2018).

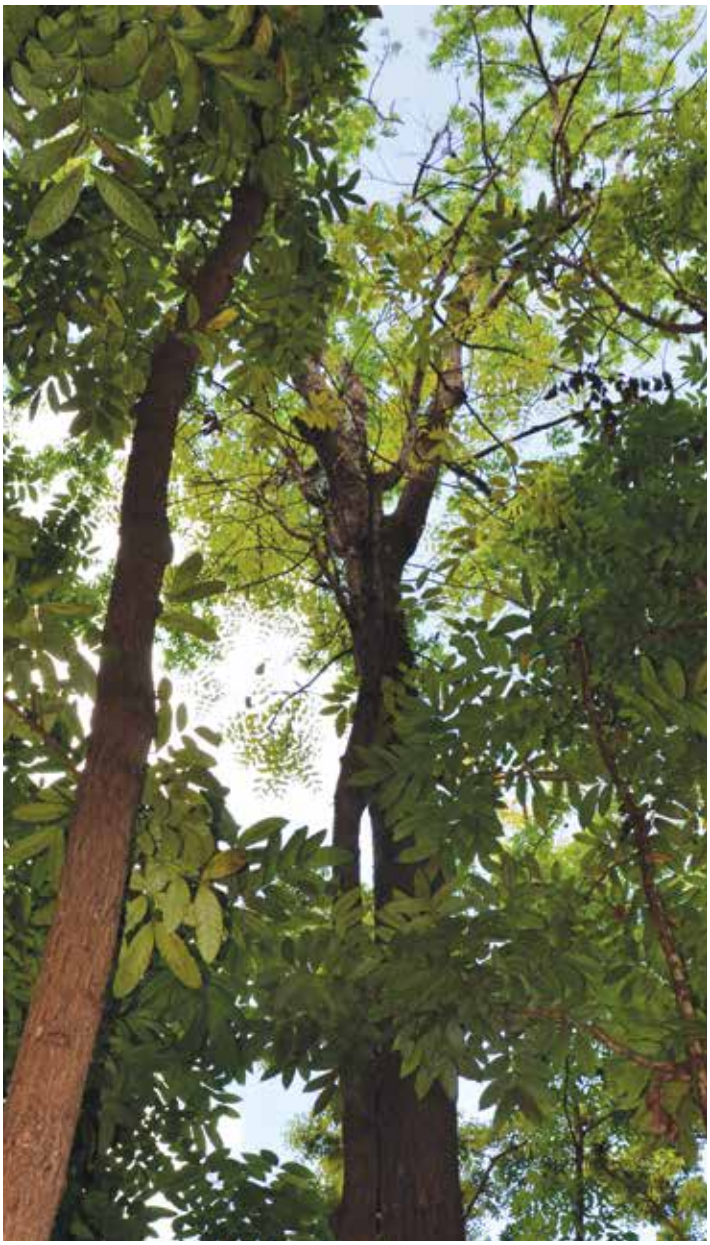
Figure 3. Author Jonae Sayama displays the wood of Honduran mahogany. It is one of the best-known and most valuable hard woods in world commerce.

Non-Wood Uses

Mahogany can be a component in agroforestry systems. It can be a windbreak that provides shelter and shade. It can also be used in landscaping. Most important, it is used in reforestation and afforestation efforts, particularly for improving soil in denuded areas (Krisnawati *et al*. 2011).

Flowering and Fruiting

The reproductive stage in mahogany starts at 12 years of age (Lamb 1966). Flowering on Guam is difficult to observe because of the great height of the mature trees. Fruiting is apparent from February through April. The fruit is a brown woody capsule or pod (Figure 2c) that is 12-17 cm long and 8-13 cm in diameter. Each fruit contains 30-70 seeds. The seeds are reddish brown in color and winged. The wings aid in dispersal. Seeds are typically 7-10 cm long and 2-3 cm wide. The dry season favors the opening or splitting of the fruit and the dispersal of the seed. The number of seed produced each year can vary considerably (Krisnawati *et al*. 2011).



Reproduction

Mahogany reproduces by seed (Figures 4a-i). On Guam there are two approaches to preparing seedlings for planting in the field. The first method is to collect seed from beneath mature trees (Figures 4a, 4b, and 4c), germinate them in greenhouse flats (Figures 4d and 4e) and transfer the sprouts to individual pots (Figures 4f and 4g). This is the preferred method as it results in vigorous seedlings with unchecked growth. After ten weeks, the potted seedlings are ready for planting in the field (Figure 4h). Avoid allowing the seedling to become pot bound as in areas affected by typhoons it is desirable to have tap roots that penetrate deeply and provide firm anchorage for the tree. A second or alternative, but less desirable, method is to uproot seedlings from the forest floor (Figure 5), transplant them into pots in the greenhouse, and later plant them in the field. It is less desirable, because these seedlings may be stunted.

Seeds germinate 10-30 days after sowing. No pre-treatment of seeds is required (Krisnawati *et al*. 2011). 80-90% of seeds are viable and produce seedlings (Lamb 1966). The storage life of seeds is reported to be short-lived (Krisnawati *et al*. 2011).

Figure 4a. Capsule.

Figure 4b. Seeds in one capsule.

Figure 4c. Individual winged seed.

Figure 4d. Starting seeds.

Figure 4e. Seedlings.

Figure 4f. Potting seedlings.

Figure 4g. Seedlings in greenhouse.

Figure 4h. Field planting.

Figure 4i. 2.5-year-old tree.

Figure 5. An alternate, but less desirable, propagation method is to uproot seedlings from the forest floor and pot them in the greenhouse for later field planting.

Planting in the Field

The best planting time is at the start of the rainy season. A hole should be dug 46 cm deep and compost or other organic matter mixed into the excavated soil. The young tree is planted at the same soil level as in the pot. The site should be watered generously and covered with a mulch, like leaf litter, to conserve moisture and suppress weeds. On the Pacific Island of Niue, the recommended spacing for mahogany in a woodlot is 3 x 4 m for a total of 833 trees per hectare (Coker and Tobin 2017). Growth in the field is rapid and trees are erect. Two and one-half years after planting the seedling will have developed in a tree that can be cut into poles (Figure 4i).

Management

Once planted in the field mahogany requires little care. An exception to this is during the first year, to maintain a weed-free environment. Mahogany does not require fertilizers, nor does it need irrigation. Natural rainfall is sufficient. The trees are remarkably free of insect pests and diseases. No pest management programs are recommended.

Mahogany plantings can be harvested for timber at 35 years of age (Thomson *et al*. 2018), though selective thinning for poles can begin after 2.5 years.

Guam Case Study

Guam's original mahogany planting is located at Piti Guns (Figure 6), a unit of War in the Pacific National Historical Park that features three WWII Japanese coastal defense guns. 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. The trees are protected as a part of the national park and have never been harvested. These towering trees with their highly desired wood form a forest that is rarely observed on Guam.

The mahogany trees were studied in 2018 (Bevacqua and Cruz 2020) to compile information on the trees that can be used in interpretive programs to enhance the visitor's experience at Piti Guns.

The immediate objectives of the study were to document the history of the mahogany trees. prepare a map showing the extent of the forest (Figure 7), conduct a survey of a sample of trees to determine diameter, height, and vigor; and assess threats to the forest.

Historical Background to Guam Case Study

To improve island food production, the U.S. government operated an agricultural experi-

Figure 6. Guam's original mahogany planting (1928) is located at Piti Guns, a unit of War in the Pacific National Historical Park that features three WWII Japanese coastal defense guns.

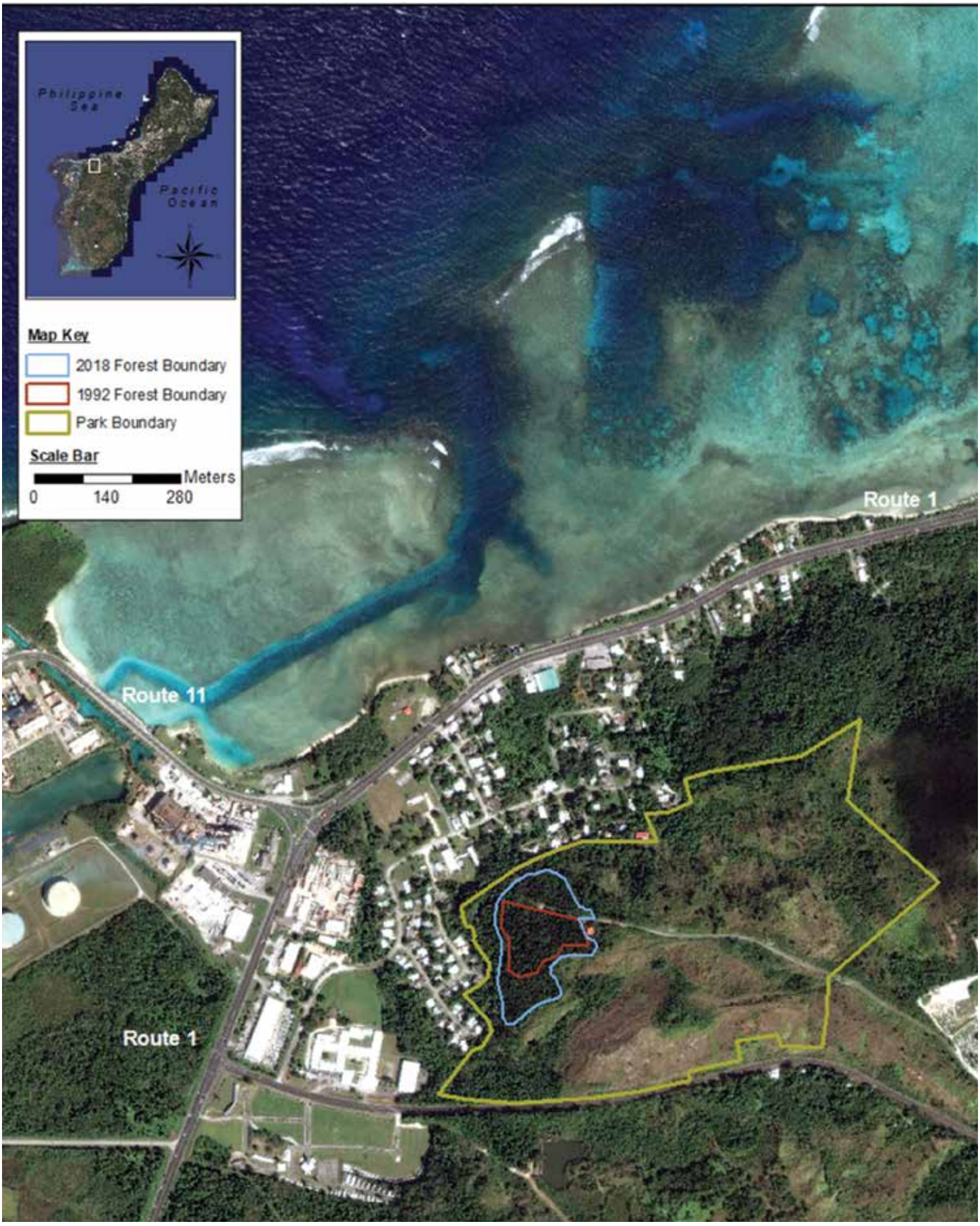


Figure 7. Map of Guam showing the location of the Piti Guns Unit of War in the Pacific National Historical Park. The unit boundary is marked in yellow. The boundaries for the mahogany grove are marked in red for 1992 and blue for 2018.

ment station in the village of Piti from 1909 to 1932 (Jennison-Nolan 1979). 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* (Colebr.) Kuntze) 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 mahagoni (L.)*Jacq.). 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.

In 1992, 64 years after the initial planting, a survey of the mahogany trees (Jurgensen 1992) recorded 185 mature trees that covered an area of 1.3-ha (Figure 7). 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 trees 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 few have attained the success, other than Palau, that is evident at Piti Guns on Guam.

Results of Guam Case Study

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.

Measurements were recorded for the 32 mature trees located within a 0.21 ha sample area. The results of this survey indicate an average DBH of 60.7 cm and an average height of 17.7 m in the sample area. Estimates for basal area and wood volume are 46.4 m^2/ha and 827.6 m^3/ha. There is a high level of natural regeneration with an average of 77,500 seedlings/ ha in the forest.

Of special interest are the five trees in the sample area that were planted in 1928. In the 1992 survey, 65 years after planting, these five trees have an average DBH of 46.7 cm and a growth rate of 0.72 cm/year. In the second survey in 2018, 92 years after planting, 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 rate of growth over a 90-year period. Three of the five trees were rated as having high vigor with straight trunks and ample foliage. 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.

There are no eminent threats to the mahogany grove. The trees' good health is evidenced by their robust growth and active natural regeneration. Thousands of seedlings can be observed on the forest floor. 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.

The trees appear well-able to withstand competition from invasive plant species. African tulip tree (*Spathodea campanulata* P. Beauv.), tangantangan (*Leucaena leucocephala* (Lam.) de Wit), pal-

ma brava (*Heterospathe elata* Sheff.), and various vines are present at Piti Guns, but they do not encroach into the mahogany stand. Feral pigs root on the forest floor, but their activity does not appear to be detrimental. 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.

In summary, 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.

Mahogany Forest at Cotal

On Guam, a second Honduran mahogany forest can be found in the Cotal Conservation Area along cross-island road. This is a mixed planting that also includes eucalyptus and acacia trees. It covers an area of 1.4 ha. The oldest mahogany trees are 40 years old and have a height of 24 m. These trees were started with seedlings transplanted from the Piti forest.

The trees at Cotal are managed by the Forestry Division of Guam's Department of Agriculture. Forestry staff report the wood is very dense and requires a special effort to cut with a chain saw.

Palau Case Study

Palau shares a similar history in the introduction of mahogany. Plantations were established during the Japanese occupation in the 1930s (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).

Opportunities in Growing Mahogany

Mahogany trees in the islands of the Western Pacific pose a dilemma. They grow extremely well, but there is little infrastructure for the processing or marketing of the wood. On Guam, for example, like most of the other Micronesian islands, no timber industry exists. There is no commercial harvesting of trees for lumber and no sawmills. The economic benefits, thus, generated by the planting of mahogany would be small-scale in nature and would take the form of cottage industries or niche opportunities, such as woodlots, handicrafts, and agroforestry.

Woodlots for the production of trellis poles for farmers is a promising opportunity for mahogany. A woodlot is a tract of land set aside for the growing of trees. On Guam, for example, woodlots could be developed for the growing of poles. Following is an explanation of why it is anticipated there would be a strong demand for wooden poles that are 2.5 m long and 6-12 cm in diameter. Of the top ten vegetables produced on Guam, five or one-half are grown on trellises made of poles and netting (Figure 8). These trellis-grown crops include yard-long beans, cucumber, bitter melon, wing beans, and tomatoes (San Nicolas *et al*. 2019). Each year these five trellis-grown crops account for 60 ha of farm production (NASS 2020). The current practice is to use tangantangan as the poles in the trellis systems (Figure 9).

There are drawbacks to the use of tangantangan. The poles only have a working life of one year. Farmers must cut a new set of poles each year. Also, tangentangen can be crooked in growth habit, so not all trees are suitable to be used as

Figure 8. Each year on Guam, 60 ha of vegetables are grown on trellis systems made of wooden poles and netting. This creates a demand, conservatively estimated, of 50,000 poles per year.

Figure 9. The current practice is to use tangantangan (*Leucena leucocephala*) in the trellis systems. A major drawback is the poles have a working life of only one year.

poles. Mahogany, on the other hand, has the advantages of rapid and straight growth (Figure 10) and a long working life of up to five years. The time required for a young tree to achieve a size suitable for the cutting of poles is 2.5 years. There are advantages, thus, for farmers to develop woodlots for the production of mahogany poles for their trellis systems and abandon the use of tangentangen.

A suggested woodlot on Guam could have an area of 0.33 ha. At a spacing of 3 x 4 m (Coker and Tobin 2017), this would contain 275 trees. Assuming 80% of the trees reach the age of 2.5 years and further assuming each tree produces two poles that are 2.5 m long (Figure 10), this woodlot would yield 440 poles suitable for use in trellis systems.

Figure 10. Mahogany offers many advantages over tangantangan in trellises. This 2.5-year-old mahogany, for example, produced two poles, each 2.5 m long, with a working life of five years.

Figure 11. Mahogany could replace the native hard woods, which are in decline, in the creation of handicrafts.

Handicrafts are typically made of native hardwoods in the Pacific Islands (Figure 11). These trees are in decline (Thaman *et al.* 2006). This is especially true on Guam where ifit is the traditionally preferred wood for carving. Mahogany could replace the native hardwoods in the creation of storyboards, wooden sculptures, platters, musical instruments, and other handicrafts.

Agroforestry is a traditional Pacific Island practice of integrating trees with crops and/or animals (Elevitch and Wilkinson 2000). For thousands of years agroforestry was one of the factors that enabled the isolated islands in the Pacific to be self-sufficient (Elevitch *et al.* 2014). Current guidelines for agroforestry for the Pacific Islands recommend a mix of plant species selected for their different heights and life spans (Elevitich and Logan 2019). The result is a multi-story planting with several layers of vegetation. Mahogany could be a tall, long-term component of an agroforestry planting. It would provide, shade and shelter to the plants below, build soil, and serve as a windbreak. These benefits are in addition to its value for timber and fuel. There are also possible downsides to including mahogany. It can be aggressive and grow to dominate an agroforestry planting.

Summary

Honduran or big-leaf mahogany is one of the best-known and most valuable tropical trees in world commerce. Early plantings on Guam and in Palau demonstrate how easily the tree adapts to the environmental and soil conditions of the Micronesian Islands where it can be considered as a replacement for native hardwoods that are in decline. Mahogany reproduces by seed. Trees can be harvested for timber at 35 years of age. The wood is principally used for furniture and cabinets, but can also be used for wood carvings, veneers, boatbuilding, musical instruments, and construction materials. For Micronesia, it is recommended that mahogany be planted in small woodlots for the production of trellis poles or as a component in an agroforestry planting that includes a mix of plant species selected for their different heights and life spans. Mahogany can contribute to island economies through the development of cottage industries and niche opportunities that enhance self-sufficiency and sustainability.

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Back cover: A valuable and distinctive feature of Honduran mahogany is its straight and erect growth.

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