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Niue Forest-land Restoration – design, methodologies, practice and recommendations

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Niue Forest-land Restoration – design, methodologies, practice and recommendations

Russell Coker

and

Daniel Tobin

REGIONAL OFFICE FOR ASIA AND THE PACIFIC FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS and
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Photo title page courtesy Daniel Tobin

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Contents

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During the conduct of this two week assignment, we have had the support of Peter Newsome, Landcare Research Project Manager of the Niue Forestry and Protected Area Management Project, Poi Okesene, Director of DAFF, and forestry staff based at Vaipapahi agricultural farm.

Daniel Tobin, as well as co-authoring this report has produced the video output that is part of this assignment. We would also like to thank Peter Newsome and Larry Burrows for reviewing the script and Anne Austin and Cynthia Cripps for editing the final version.

Abbreviations

DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agriculture Organization
FPAM	Forest and Protected Area Management
GIS	Geographic Information System
NZAID	New Zealand Agency for International Development
SPHa	Stems per hectare

Glossary

Toona	Toona ciliata var australis / Red Cedar
Mahogany	Swietenia macrophylla / Honduran mahogany
Stocking	The number of live trees (seedlings) expressed as trees (seedlings) per hectare
Noni	*Morinda citrifolia*
Moota	*Dysoxylum mollissimum*
Kafika	*Syzygium inophylloides*
Toi	*Alphitonia zizyphoides*

Executive Summary

The terms of reference were implemented during two 1-week visits between 3 March and 13 May 2017. The assignment included supply of forestry equipment and production of a training video.

Trials with several tropical plantation species began as early as 1958 but in ensuing years focused on just two species, large-leafed mahogany and toona. Over 300 ha were established in various configurations in the years leading up to 2004 when Cyclone Heta wrought considerable damage to the Island. Today, few plantations remain in a condition to yield high-value saw-logs upon maturity.

While there has been sufficient moisture storage to support average plantation growth on sites with deeper soils, on sites with shallow soils, tree growth displays dead tops, short stems and heavy branches. Woodlots planted at wide spacing have too few trees to select enough trees of good form for a final forest crop. Furthermore, inter-cropping between rows of trees has not been sustainable so a return to higher stocking and rectangular spacing is advocated.

There are no practical silvicultural interventions to restore old forest plantations because, in most cases, the trees have already developed poor form, in many cases there has been complete or significant loss of stocking, and in all cases it is too late in the rotation to prune or to rectify low stocking.

If mahogany planting is to be promoted, selection of suitable soils and early silvicultural treatment on currently non-forested land are the key success factors. However, as there is no current market for mahogany or toona on Niue, there is little interest from landowners in participating in plantation development or management unless it is subsidized. Alternatively, although mahogany was selected for the forest restoration demonstration woodlot and training, the silvicultural practices advocated in this report can be adapted to establish and manage plantations of other forest species, for example kafika or sandalwood.

Sandalwood establishment is advocated by DAFF and would offer earlier returns from heartwood, nuts, and perhaps fruits from host plants.

The design and techniques for managing mahogany were used to retrain staff of the Department of Agriculture, Forestry and Fisheries and to establish a small demonstration woodlot at the Vaipapahi Agricultural Farm. The process was recorded on video and is available at the following Youtube link. https://www.youtube.com/watch?v=LOroySzxCvc

1 Introduction

The FAO, with financial support from the Global Environment Facility (GEF), is assisting the Government of Niue with the Forest Conservation and Protected Area Management (FPAM) project. The project's main objectives are to strengthen biodiversity conservation, reduce forest and land degradation, and enhance the sustainable livelihoods of local communities living in and around protected areas.

The primary role of Landcare Research is to implement activities that enable the Niuean communities to sustainably manage forest resources both in protected areas and other land.

The forestland restoration project is relevant to this objective because one way of reducing land degradation is to establish new forests of either introduced or native trees on previously cleared and degraded forest land. Retaining land in trees for many years will allow shallow and nutrient-poor soils to recover, thus contributing to sustainability.

Even small woodlots will add to the biodiversity of large areas of managed scrubland and fernland, where tall trees are largely absent. The stability offered by new forest pockets will provide animal habitat and allow the recovery of understorey native plants, largely spread by birds.

Small forests may also enhance livelihood by providing fuelwood, wood for carving or handicrafts, poles, and other products.

2 Background to plantation forestry on Niue

Trial plantings of several species used on other pacific islands were established in the late 1950s. Frost and Berryman (1966) in their report "The timber resources of Niue Island" recorded that before 1961 several exotic species had been introduced for shelterbelt evaluation, including:

- *Pinus caribaea* (1961)
- *Eucalyptus saligna* (1961)
- *Eucalyptus botryoides* (1961)
- *Eucalyptus pilularis* (1961)
- *Eucalyptus ficifolia* (1961)
- *Eucalyptus phaceotricha* (1961)
- *Tectona grandis* (teak 1963)
- *Casuarina equisetifolia* (1959)
- *Swietenia macrophylla* (large leaf mahogany 1958)

The trials were located on the Vaiea-Hakupu road adjacent to what is now a large noni farm. During a visit to this site (as part of the current assignment) other species, including *Gmelina arborea* and *Araucaria* spp. (Queensland), were also noted.

The government of Niue decided that future plantations should concentrate on large leaf mahogany (*Swietenia macrophylla*), referred to as mahogany in this report, and Australian Red Cedar (*Toona ciliata var australis*), referred to as toona.

2.1 Mahogany

Mahogany is a suitable choice: the timber is relatively durable – "life in ground" (from Fiji grown samples) is known to be over 10 years (similar to Western Red Cedar); it is at the top of the moderately durable band; and is suitable for a 15-year life when used as decking, for instance. Toona, by comparison, has an equivalent life of only 3 years. Other features that commend it are:

- Good early height growth and at 3 × 4 m spacing, and early pruning of side branches, will yield a straight stem of six metres, suitable for a future saw-log.
- It is deciduous and drops its leaves in the dry season, a useful adaption for Niue's shallow soils where severe soil water deficit can occur in any year during the dry season.
- It has a strong taproot (in naturally seeded trees) and buttressing (in mature trees), which insure some resistance to damage from tropical cyclones.

Figure 1. Inside the 30 year old Vaipapahi mahogany stand.

In other Pacific locations, both toona and mahogany are subject to attack by stem borers, which damage the early form of trees. We saw no active evidence of the stem borer on Niue during two, week-long, visits.

2.2 Toona

Toona, while undoubtedly vigorous, shows little evidence that it can yield straight saw-logs of useful length. Whether this is a result of poor seed-lots or some other factor is unknown, but it is also likely that wide initial spacing has had a deleterious influence on form. In Queensland, toona yields a high value timber which is initially resistant to insect attack. The timber has many uses, particularly for furniture.

Figure 2. One of very few good examples of toona.

2.3 Indigenous species

Indigenous species such as kafika, moota (canoe wood), and toi should also be considered for plantation establishment and management. These native trees are regularly conserved by landowners during land clearing for cultural reasons. Kafika, in particular, has excellent straight form when grown at close spacing and is renowned for its strength, for example, for reef fishing poles or lifting bars on vaka, and for its ground-hardiness as posts.

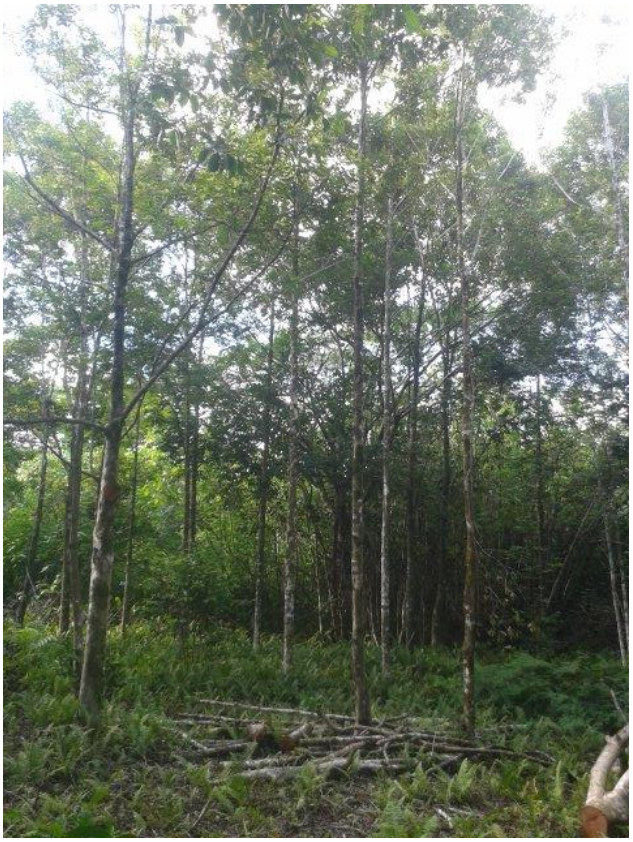


Figure 3. A pole stand of kafika showing very good form.

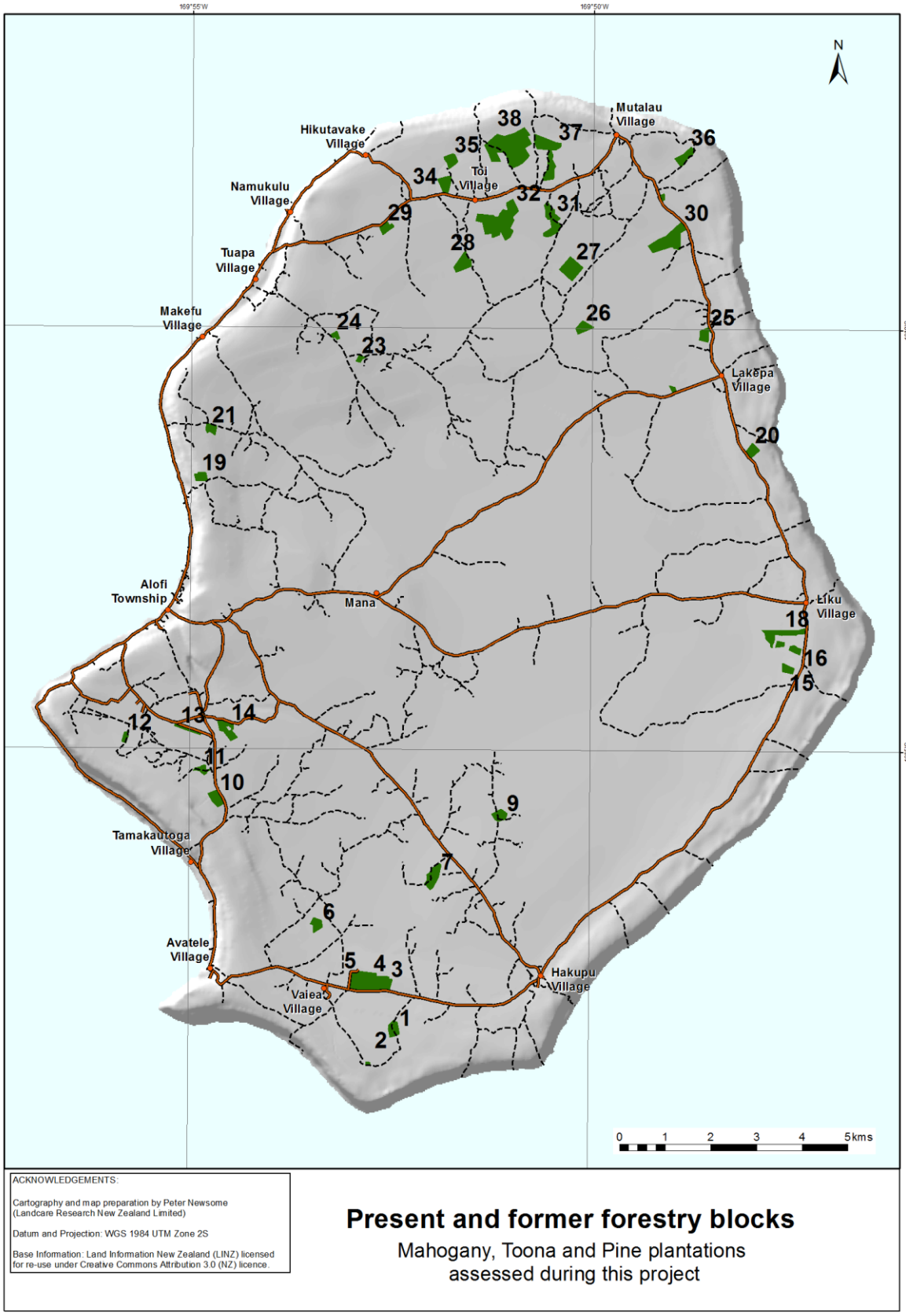
2.4 The first reforestation era

In the period 1992–1993, 32.8 hectares of mahogany and toona plantations were established, with New Zealand financial assistance, at three locations on government land. These plantings included significant areas of line planting under natural forest.

2.5 The second reforestation era

In 2000, a 3-year forestry assistance project began, funded by NZAID. During this time, several small plantations were established on private land mainly at wide spacing (10 metres between rows) to allow intercropping with taro and bananas. The subsidized plantation management was discontinued in 2003.

Cyclone Heta in 2004 damaged some plantations (and natural forests), especially near the north western coast, and a period of salvage-logging of fallen native timber species ensued. Two portable “Mahoe” sawmills were used during this period. As at May 2017, both they and the former main mill are in an advanced state of decay.



Map 1. The location of present and former planted woodlots assessed during this project.

3 Survey of existing forestry plantations

Nineteen of the 34 plantation sites on Map 1 were re-located by driving or walking to the mapped site, and their state is noted in Table 1 (referenced to the site numbers on Map 1). Not all the plantations were found because, either the plantation had failed completely, or the land had been converted to another use in the 15 or more years since planting. A single, more recent, planting on private land was also found alongside the Alofi-Liku Road.

3.1 Survey result

Our survey of former forest plantations shows that those planted on shallow soils have suffered dieback during seasonal drought.

On some sites, planting was at wide row spacing to accommodate inter-crops, but, due to low soil fertility, inter-cropping was only viable for one or two seasons and the sites have since been abandoned. Remaining trees in these row plantings have short stems and large branches (e.g. Map 1 sites 14 and 11).

Figure 4. Line planting of mahogany showing dieback due to past drought (left) and short stems with heavy side branching (right).

The best plantations (those with potential to yield good merchantable timber) are those with traditional 3 × 4 m spacing planted on deeper soils.

Figure 5. An example of a well-stocked stand planted at 3 × 4 m spacing.

3.2 Specific findings

3.2.1 Trial plantings (pre-1992)

The plantings on Vaiea-Hakupu road are of historical interest only; however, they could be useful for seed collection, for instance, *Casuarina equisetifolia* is a suitable host plant for Sandalwood and produces excellent firewood. Remaining specimens of *Araucaria* spp. are impressive, and similar trees have been planted around some villages for ornamental purposes.

3.2.2 First era plantings (about 1992–1993)

The airport plantation (site 13) is on a very public site, but of poor form, with short stems and large branches, partly because it was planted at wide spacing, and partly, anecdotal evidence suggests, because of cyclone damage. This stand, which attracts adverse publicity, could be inter-planted with mahogany (or kafika) which, with side-shading from the current trees, would grow with good form. At a later date, the older un-merchantable mahogany could then be removed. A stand of kafika has recently been established adjacent to the mahogany.

The other stands from this era have no apparent cyclone damage, perhaps because they are located on the east coast (in the case of Liku) or they are plantings at Toi (Sea track road), which are sheltered within natural forest. These plantings are too advanced to warrant any stand improvement or restoration.

Where mahogany has been planted in lines cut through remnant indigenous forest, the under-planted mahogany is of good form. Although thinning to remove malformed and unthrifty trees could improve diameter growth on the remaining trees, this would also damage the natural forest under-storey. Any thinning should be delayed until there is a local market for mahogany logs.

The toona stands are of poor form with short trunks and very large branches, the biomass is large, but planted areas are remote and the majority of trees are unsuitable for commercial use as timber.

3.2.3 Second-era plantings (2000–2003)

The window for pruning second-era plantings to seven metres has passed and future management should only involve cutting vines that continue to pull over slender saplings, and thinning unwanted trees to improve diameter growth on the remaining trees. As these are not government-owned, it would be necessary to engage the owners in managing the few stands that are worthwhile. Sites 29, 1, 2, 3, 7, 19, and 9 have potential to yield merchantable timber.

Table 1. Current state of ex-forestry plantations and woodlots

Map Site	Status	Recommendation
3 Vaiea farm	Original trial plantings from 1958 onwards	Retain as arboretum
29 Vaipapahi farm	Best stand on Niue	Retain as demonstration stand and seed source
4,5 Vaiea	Converted to Noni farm	Delete as forest block
14,10,21	Planted on shallow soil, dieback	Abandon
1,2,7,19	Well stocked	Retain, thin to retain trees of good form
11,34	Few large shelter trees	Abandon
12,25,6	Not located	
9	Average low stocking	Retain. Good site
38	26.4 ha planting in natural forest	Retain, no treatment of mahogany areas needed
13	Airport stand	Short stems large branches highly visible
15,16,18	1992 era. South of Liku	Too late for intervention

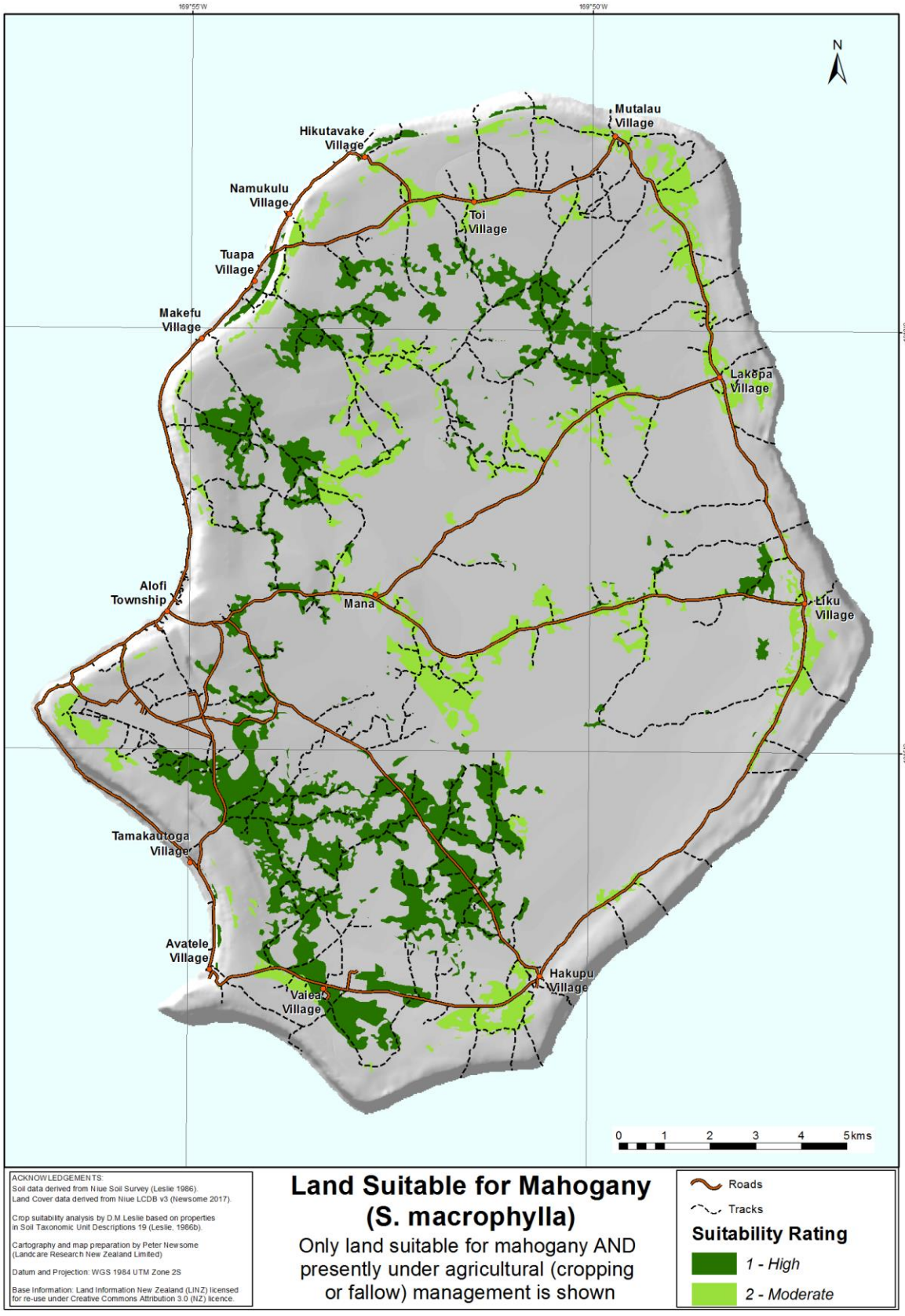
4 Forest land restoration

4.1 Relationship of soil type to mahogany growth rate and form

Several earlier reports have mentioned the shallow soils and low water-holding capacity of Niue soils. Frost and Berryman (1966) remark that variable growth of mahogany might be related to variation in soil depth, Widdowson (1965) and Leslie (2015) also identify soil depth as a major issue. Leslie (2015) identifies soil types suitable for crops including mahogany and other trees. Comparing the forest sites in Map 1, it was evident that, in general, the best stands are on soils recognised by Leslie as moderate to good sites and the poorer stands are on soils of lower suitability.

Map 2 combines Leslie's (2015) soil suitability data with the latest land cover map (Newsome 2017) and shows the areas where mahogany could replace disturbed non-forest land on good growth sites results. This is where future planting could be directed/ encouraged.

Converting these better soils to plantation would discourage them from being returned from fallow to short-term cropping. Under forest, the recycling of nutrients from leaf litter, reduced daytime soil temperatures, and related soil moisture retention (Widdowson 1965) would sustain the productive base of the soil – an aim of the FPAM project.



Map 2. Areas recommended for new plantation forests, combining suitable soils and land presently fallow.

4.2 Demonstration forest establishment and management

The steps involved in plantation management were recorded on video with the aim of leaving a record to bridge the loss of institutional memory due to staff changes through time. This activity doubled as training for 5 DAFF Forestry Section staff. The 0.25-ha demonstration stand on the Vaipapahi Agricultural Farm is in a readily accessible location for landowners interested in establishing mahogany or other plantation forest.

The outline below closely follows the script for the video "Sustainable Establishment and Management of Mahogany Woodlots on Niue", available on YouTube at the following link:

https://www.youtube.com/watch?v=LOroySzxCvc

The important messages in the video are:

- Select a good site with deep fertile soils (Map 2)
- Plant up to four times the number of final crop trees that are required, at 3 × 4 m spacing
- Maintain the crop in the first few years by weeding
- Prune as early as possible to 7 metres and thin to remove trees that hinder the growth of the final crop trees.

As a result of the review of existing plantations, the soil limitations, and the overall objectives of the project, the authors decided that woodlot establishment, management, and training should promote rectangular spacing of 3 metres between plants by 4 metres between rows (833 trees per hectare).

The advantages of 3 × 4 m spacing over wide-spaced line planting were explained:

- More trees to choose from for the final crop
- Side shade to promote small branches and height growth
- Early crown closure so there will be cooler soils and less water loss from soil.

4.2.1 Estimating stocking per hectare, using a fixed-radius circular plot

The most efficient way to estimate the stocking of either a newly planted woodlot or an established forest is to count the seedlings or trees within a known area. Simply choose a centre point objectively and with a fixed radius mark the outside of a circle with spray paint, leaves or kick marks on the forest floor. A circle with a radius of 12.61 metres gives an effective area of 500 square metres (actually 499.74 m^2).

Ideally, the radius should be increased as the land slope increases to maintain the horizontal area at 500 square metres; however, Niue is so flat that the changes required for the radius would be of little consequence.

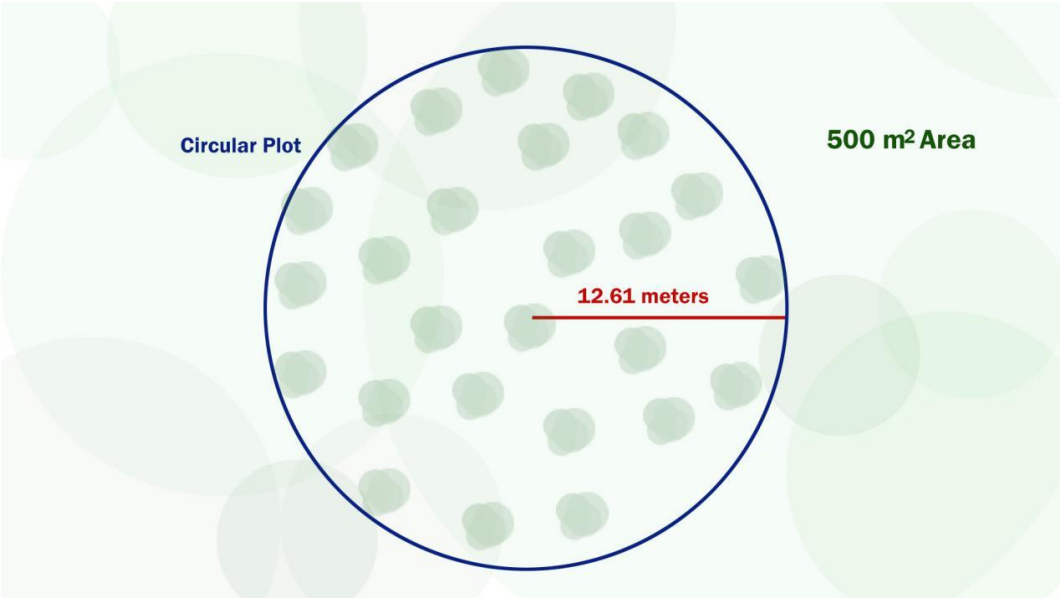


Figure 6. Determining a 500 m^2 plot.

Given that 500 square metres is 1/20th of a hectare, a simple way to calculate the stocking (stems per hectare) of seedlings or trees is to count the number of stems within the perimeter and multiply by 20. For example, 25 seedlings inside the circle is equivalent to 500 stems per hectare. It is best if the sample is repeated a number of times throughout the stand and the results averaged. For example, for seedlings planted at 4 × 3 metres there should be 41.5 seedlings inside the perimeter. In practice, while there is always some variation, the real result could be anywhere between say 38 and 45 seedlings, however, this is a quick way to estimate stocking. Trees planted at 4 × 3 metres spacing (833 stems per ha) will commonly sample between 760 and 900 stems per ha in practice.

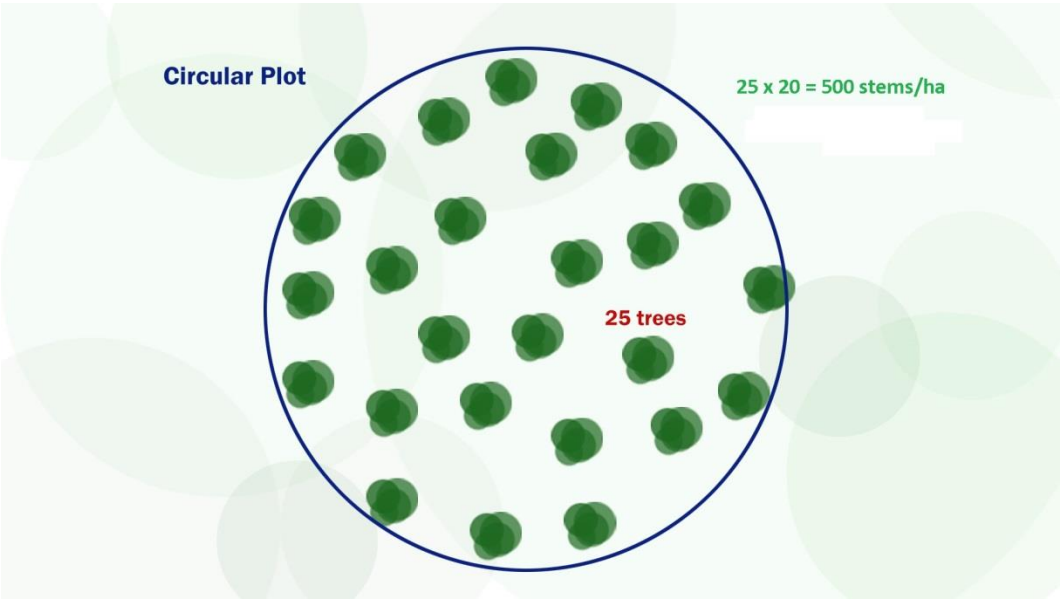


Figure 7. Calculating the number of stems per hectare.

4.2.2 Orientation of rows and plant spacing

For the chosen rectangular spacing for mahogany, lines should be cut at 4-metre spacing and plants should be spaced at 3 metres in the row. Where there is no overhead vegetation, row orientation to maximise light is not important and it is better to have the rows visible from tracks and roads for ease of checking, maintenance (weeding), and pruning.

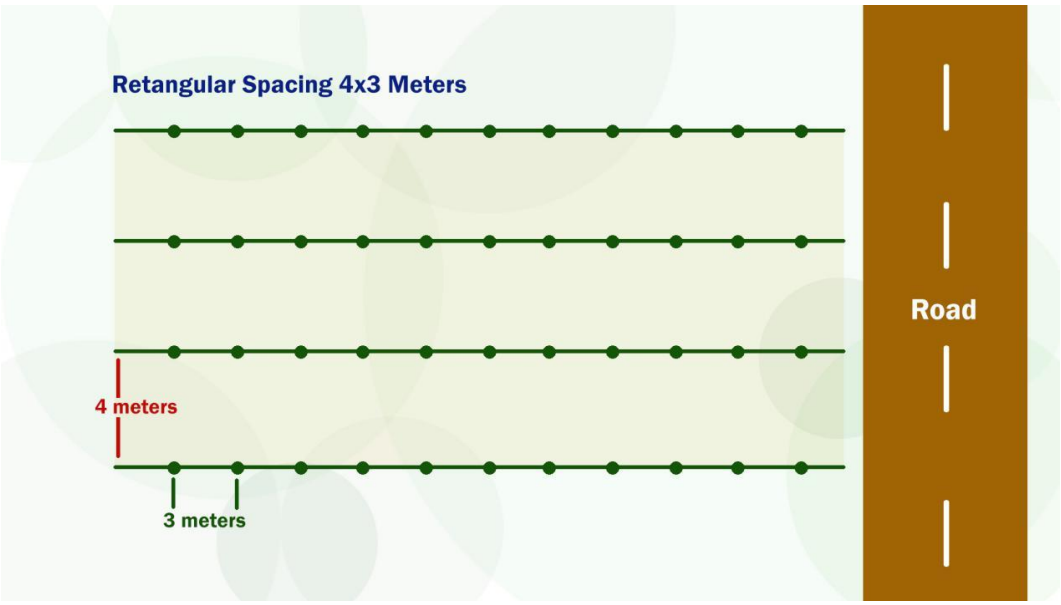


Figure 8. Ideal orientation of rows and plant spacing.

It is not necessary to completely clear the area – only remove vegetation that restricts growth of planted seedlings or reduces light. Complete clearance, reduces biodiversity and requires more work.

The spacing can be varied for other species, for instance sandalwood may be planted at 4 metres between rows and 4 metres between plants (approximately 625 stems per ha)

4.2.3 Planting

Holes should be dug to sufficient depth to cover roots and avoid coral and rocks. In many places on Niue it will not be possible to even get to 25 cm depth. Soil depth may be variable so it is permissible to move the spacing in the row to get the best planting site. It is important to get as much soil back into the hole as possible and gently shake the plant while back-filling so that the soil falls through the roots to reduce any cavities filled with air. Firm the soil to support the seedling in an upright position and use approximately 100 ml of water to wet the soil around the roots as soon as possible after planting. This is not necessary if rain is probable in the next 12 hours or if it has just stopped raining.

Note that in the next diagram the lower leaves have been “stripped” to reduce water loss due to transpiration. This increases the chance of the plant surviving transplanting and it will soon grow new leaves as long at the growing tip is not damaged.

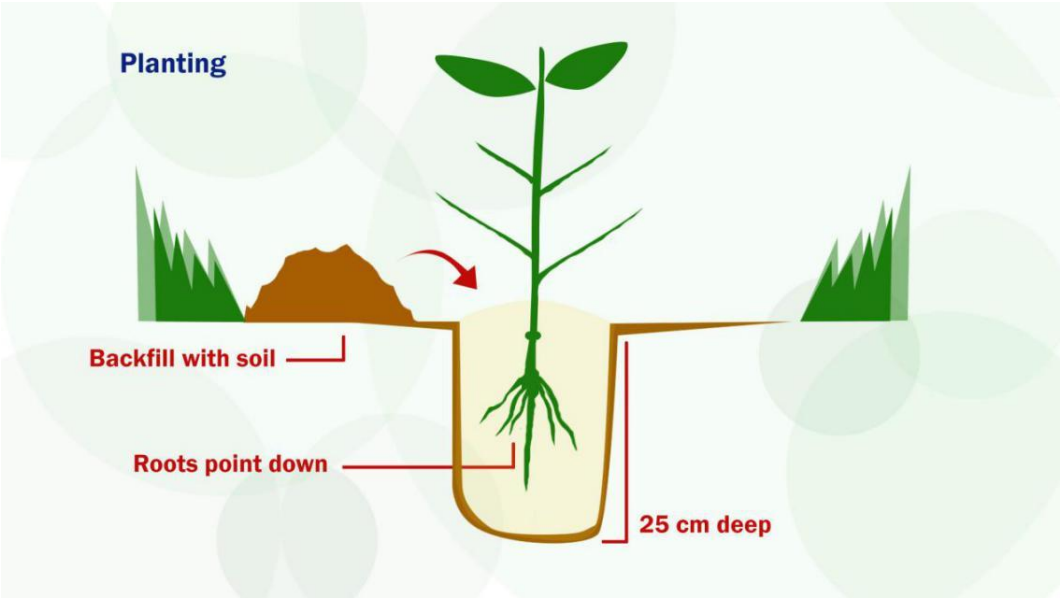


Figure 9. Preparing the hole and planting the seedling.

Seedlings from the partial shade of the forest floor may suffer sun-burn when first moved to an exposed planting site. To avoid this, they should have a makeshift sunshade for a few days until they become acclimatised. Note, however, that although this is recommended in the video, sun shades were not provided on the initial plantings at the demonstration forest and, apart from a little sun scorch on the first leaves, the seedlings were unaffected. Some references in the literature suggest that shading is **not** necessary.

As much soil as possible should be retained around the roots and plants should be kept in a plastic bag while they are waiting to be planted to minimise desiccation. If the roots dry out the chances of seedling survival are much reduced.

Figure 10. Sun scorch on a mahogany seedling recently transplanted from the shade of the forest floor.

Figure 11. Keeping seedling roots moist in a plastic bag while waiting to be planted.

4.2.4 Direct seeding

According to the literature (Mayhew 1998), mahogany can be directly seeded into the field. Successful germination may only be 40% but by putting three seeds at each site the chances are high for most sites to have at least one seedling. The extra seedlings at any site can then be transplanted into any blank sites. The practice is apparently common in Fiji, where experience suggests that field-grown seedlings may be more resistant to wind-throw during cyclones. This may be because container-grown seedlings or seedlings that have had the taproot cut do not anchor the plant as firmly.

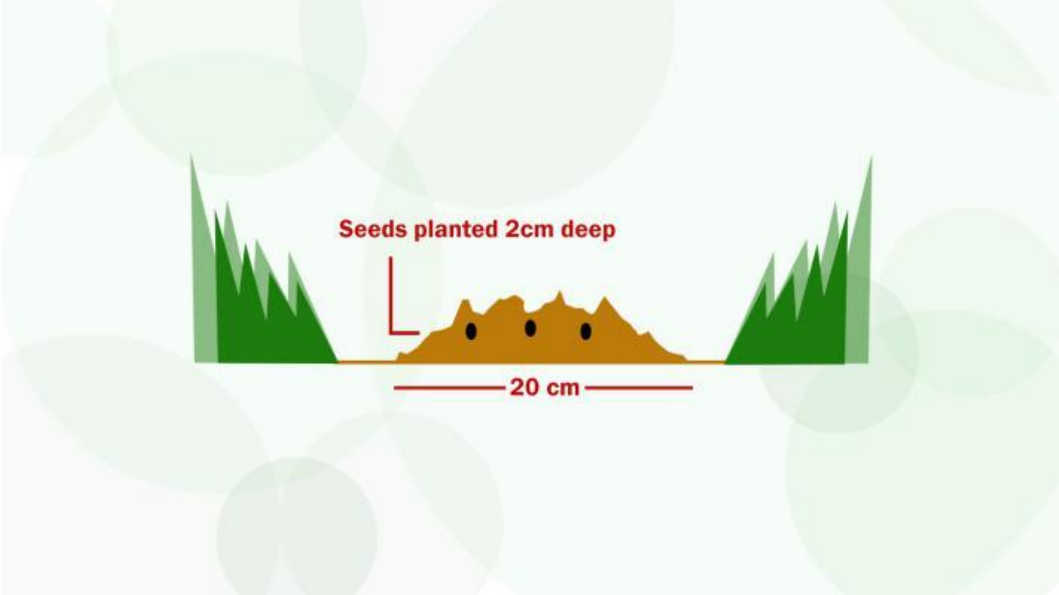


Figure 12. Establishing seedlings from seed.

4.2.5 Weeding

Weeding is necessary at regular intervals to remove climbers and other plants that keep light from the seedling. Vines, especially, can pull the young tree from the vertical position, causing malformed growth or breakage. Weeds around the base of the plant compete for moisture and nutrients, especially in the first 2 years until the tree roots expand into deeper soil. “Mile-a-minute” weed (*Mikania micrantha*, and other species of similar habit) can be a particular problem in the first few years.

Figure 13. Vines climbing up a tree seedling.

4.2.6 Pruning

The aim of pruning is to remove branches that cause large knots in any lumber that is cut from the log. The log is the most valuable part of the tree.

The growth in height of mahogany on good sites is rapid, and may leave few branches to remove on the lower stem. A ladder or pole saw will be necessary to remove higher branches. In the photo below it is 4.5 metres to the first branch and no pruning has been necessary yet.

The straightest and most vigorous trees should be selected for pruning and effort should not be wasted in pruning branches from trees that will not make the final crop.

Pruning should result in a log clear of branches for 6 metres. Because of the buttress at the base of the trunk pruning needs to be to 7 metres above ground level, as shown in Figure 15 below.

Figure 14. Three year old mahogany showing typical growth on a good site.

No more than 40–45% of the tree crown should be removed otherwise the growth rate may be reduced. This means that the average tree will be about 11–12 metres tall before it is pruned to 7 metres.

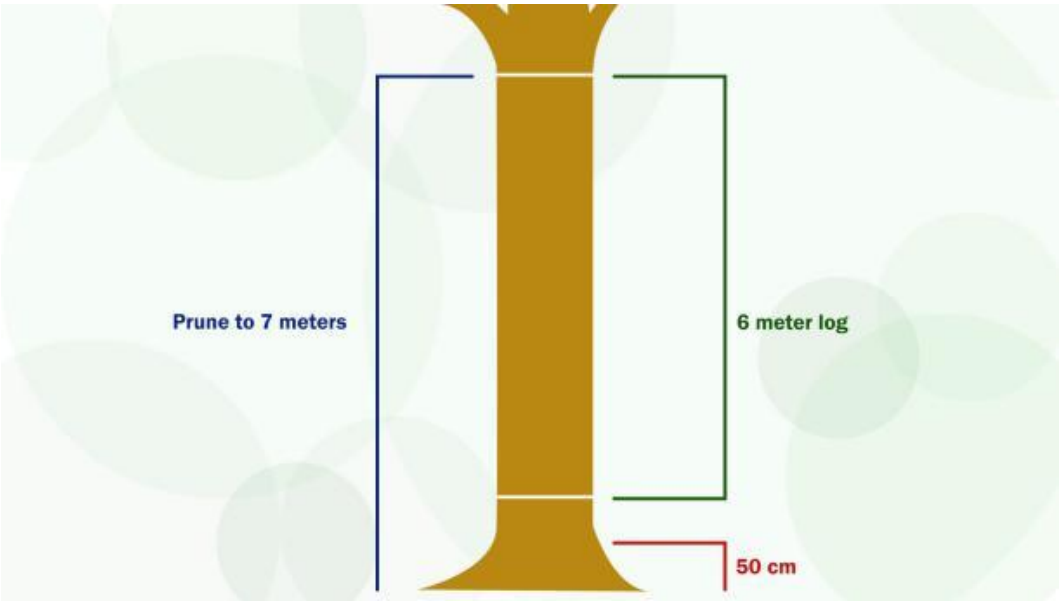


Figure 15. Prune to 7 m in order to be left with a 6-m sawlog.

Growth data are not available for mahogany in Niue, so the following schedule is based on Fijian data (adapted to reflect poorer soils of Niue).

Table 2. Suggested pruning schedule for mahogany in Niue

Tree age	Tree height	Prune height
18–24 months	~ 5 metres	2.5 metres
24–36 months	~ 8–10 metres	4.5 metres
48–60 months	~ 11–14 metres	7 metres

4.2.7 Thinning.

Although the demonstration woodlot has a planted density of about 800 stems per ha, only 200 stems will be necessary for the final crop at age 45–50 years. If the trees are not thinned out they will remain slender and have very little value. Thinning out trees provides more light, water and nutrients for the remaining trees so they will grow faster and fatter. Thinning is usually done in stages because if it was done all at one time the stand would be weakened and liable to blow over in a cyclone.

Leaving some of the unwanted trees for later thinning maintains side shade to keep the final crop trees growing straight, controls weeds, and retains options for using some of the trees as they get larger, for poles. Selection of the best trees should be made as soon as possible so effort is not spent on trees that are going to be cut out.

Figure 16. DAFF forestry worker, wearing safety gear, thinning mahogany as part of practical safety training.

Periodic thinning of unwanted trees should approximately follow the schedule below. This schedule is based on Fijian data; the age recommended for thinning has been increased to allow for slower growth on Niue's poorer coraline soils.

Table 3. Suggested thinning schedule for mahogany in Niue

	Trees per hectare	Plantation age
Initial planting approx. 830 stems per ha	800 trees	At 0–5 years
Reduce to	600 trees	At 5–10 years
Reduce to	400 trees	At 15–20 years
Reduce to	200 trees	30 years and grow to maturity (about 50 years)

4.3 Propagation of tree seedlings

4.3.1 Tree wildings.

To implement the demonstration plantation it was necessary to find planting material from the natural forest, given there were no bagged seedlings available in time for the project.

The 30-year-old stand at Vaipapahi Agricultural Farm had recently been under-brushed (cleared of ground-covering plants and debris) and there were several hundred seedlings on the forest floor. These seedlings were probably from the most recent seed-fall because mahogany seed is not viable for long periods unless dried and stored with fungicide.

Figure 17. Undercutting tap roots of wildings on the forest floor.

Roots were pruned in situ with a sharp spade to sever the tap root. There are two benefits of this:

- to allow the seedling to fit into the planting hole and
- to encourage the formation of new roots above the cut.

It will take about 2 months for the seedling to grow new roots.

Figure 18. A seedling, undercut 8 weeks previously showing new root growth and red paint identifying it had been undercut.

"Bare root" seedlings from the forest floor are better suited to planting when levels of soil moisture are high (i.e. in the wet season). The lower leaves should be stripped from the seedlings before they are lifted. This will reduce the water loss from the seedling while the new roots become established.

Seedlings with a stem diameter of between 1 cm and 1.5 cm at ground level and with a stem length of about 50 cm from ground level to the growing tip should be chosen for root pruning. Root-pruned seedlings need to be identified so that they can be recognised 2 months later when they are lifted for transplanting into the field. A little paint on the lower stem or some string tied around the seedling will identify root-pruned seedlings.

4.3.2 Seedling cultivation in planter bags

The project supplied 3000 PB3/4-litre planter bags. This is sufficient for DAFF to maintain a supply of mahogany seedlings for interested landowners and to provide planting material of other species for forestry projects such as the kafika plantation adjacent to Alofi airport or sandalwood seedlings for further trials.

Mahogany can be grown from seed in planter bags on the forest floor by filling the bags with forest soil, inserting seeds and leaving the bags under the canopy. This will avoid the need to construct a shade house. After germination, the seedlings can be either left on the forest floor or introduced to full light. Seedlings left on the forest floor will grow roots outside the bag. To avoid this, the bags can be suspended on chicken netting and it will not be necessary to cut off the tap root because any roots that emerge from the bag will be naturally "air pruned". Container-grown seedlings will have a more compact root system and will be more suitable for planting under dry conditions.

Natural regeneration on the forest floor is greatest during the wet season when regular rainfall triggers germination of seed. Mahogany responds in the same way and germination in containers can be stimulated by regular watering. This means bagged seedlings could be available all year round.

Very small seedlings of mahogany, kafika, and other species can also be transplanted from the forest floor.

Figure 19. The planter bags on left have been seeded with sound kafika seeds from the forest floor, those on the right show small seedlings transplanted into bags. The conditions are right for natural germination so the bags can remain on site until they are ready to move to full light.

5 Community consultation

A workshop was held on 11 May 2017 involving key farmers, village representatives, and representatives from land-related government departments. The video on establishing and managing mahogany was screened during the workshop, which prompted a conversation about the future market for mahogany and the long wait, without income, for a return on investment from forestry.

Figure 20. Attendees at video launch workshop.

At present, there is no functioning sawmill on Niue. There is, however, a chainsaw mill available that has been used to cut large-dimension lumber for outdoor furniture.

Other options for utilising mahogany include exporting logs from the Alofi wharf, perhaps in containers, many of which return to Auckland empty on the regular shipping service. The annual volume that may become available in the future is very small and unlikely to attract a premium price. Due to larger scale plantations and better infrastructure, Fiji produces large volumes of plantation-grown mahogany, has an established market, and produces a more sustainable supply than Niue could.

Another option is wood carving. There is a specialist “ebony” wood-carving tourist venture on Niue, utilising heartwood of old fallen trees of kieto (*Diospyrus samoensis).* Apart from this venture, much less carving is done on Niue than in other Pacific islands, probably because of the relatively small number of visitors to whom products could be sold. Mahogany and toona, known for their attractive wood colour and ease of working, would be well suited as craft-wood.

In the meantime planting mahogany is providing a resource for some future high value timber use – most likely local furniture manufacture or items for the tourist trade. In the interim there is value from plantations in protecting soil and encouraging biodiversity.

Commercial and residential building in Niue will probably continue to be based on imported and appropriately treated pine lumber from New Zealand. Notwithstanding this, the training focus of the assignment was on the production of pruned saw-logs of mahogany to produce clear, high-value, timber for construction, cabinetry, and craft uses.

6 Sandalwood as an alternative tree crop

The Director of DAFF, Poi Okesene, identified sandalwood as a possible complementary, high value, tree crop with a shorter maturity than mahogany. There may also be a by-product market for the nutritious seeds. Recently, 800 sandalwood seedlings and associated herbaceous host plants were raised at the agricultural farm and distributed to the community. A number of sandalwood seedlings were still available at the agricultural farm nursery during the second visit of this assignment and following The Director's vision of a small trial was established adjacent to the mahogany demonstration woodlot.

Figure 21. Row of sandalwood (and herbaceous host plant) planted in the demonstration woodlot. The poles are Gliricidia, a nitrogen-fixing plant that grows very readily from cuttings and is expected to be a suitable root-host companion.

After a literature search it was decided that readily available Gliricidia (*Gliricidia sepium)* would be a suitable woody host plant. Although Gliricidia is a nitrogen fixer and grows well on Niue it may be too vigorous and will need to be cut back.

Sandalwood is known to form host relationships with up to 500 species, including *Pinus caribaea* in Tonga. Citrus is a suitable host plant but does not grow well in alkaline soils, which are prevalent on Niue. A fruit tree known as noni (*Morinda citrifolia)* grows very well on Niue and is commercially cultivated for juice. Although there is no specific reference to it in the literature, this plant may be a suitable host for sandalwood. Apparently it grows in association with sandalwood in Tonga and some other Pacific islands. The Deputy Director of DAFF, Natasha Tohovaka, has some of the original sandalwood seedlings raised at the agricultural farm growing among wild noni plants and both species appear to be growing well.

If this proves to be a good host relationship, the techniques applied to mahogany plantation development could be modified to establish sandalwood and noni plantations, which could offer intermediate returns.

There is another possibility. Lemoncito, also known as Calamansi in the Philippines, is a small tree widely grown for its fruit, the juice of which is combined with soy sauce and chilli as an important traditional dressing for raw fish dishes. Calamansi, a natural hybrid between citrus and kumquat (Latin name, *Citrofortunella mitis)*, is cultivated in Palau, Hawai'i, and Samoa (where it is known as *Tipolo Iapani)*. This plant would probably be a suitable host for sandalwood because of its citrus genetic component, and although it is not ideally suited to alkaline soils it may grow sufficiently well to function as a root host plant for Sandalwood.

7 Community Forestry support

As part of this assignment, DAFF forestry staff have been trained in the techniques of managing mahogany, and, with adjustment to spacing, soil matching, and light conditions, these techniques could be transferred to other tree crops.

The small DAFF Forestry Section is now trained and equipped to provide advice, training, and seedlings to individuals and groups who visit the agricultural farm. The video "Sustainable establishment and management of Mahogany Woodlots on Niue" is there to provide encouragement and knowledge to individuals and groups. The strategically located demonstration woodlot can be used to provide capacity building field training.

Figure 22. Participants in the forestry field day.

8 Equipment to facilitate forestry activities

One of the requirements of the assignment was to determine the equipment required to support forest restoration and to deliver a list with recommendations and suppliers to FAO for procurement.

This is the original equipment list designed to provide basic forest management equipment for 5 DAFF employees. The equipment list was drawn up before the first site visit in the hope that the equipment would arrive during the assignment.

The equipment arrived during the second visit, was fit for purpose, and was very well received by the department.

Table 4. Equipment procured by FAO to support establishment and management of plantation forests

Operation/Purpose	Item	Number required	Recommended model
Clearance/establishment			
Trees > 40 cm	_	_	_
Fallen trees and competing scrub 5- 20cm diameter	chainsaw	1	Stihl MS231
Saplings, vines, high pruning	pole chainsaw	1	Husquavarna 525PT5
Releasing 0.5 cm to 5cm diameter	curved slasher	4	Timbersaws TS14
Saplings, vines, grass	scrub cutter (circular blade)	2	Husquavarna 535RXT
Hole digging/ cultivation/ring weeding	bush knife/bolo	4	Cold Steel Bolo Machete 97BM
Small vines, twigs	secateurs	4	e.g. Atlas Trade Forged Bypass Secateurs 215 mm
Silviculture			
Pruning branches/ singling leaders < 20 mm	loppers	4	Timbersaws Prun off Lopper
Pruning larger branches above shoulder height	curved pruning saw	4	Silky Zubat Saw 300 mm
Thinning - chainsaw /slasher (as above)	_	_	
Pruning above 2.2 m	Ladder (tall)	2	FA 4.2 – 4.2 m Forestry Ladder
	Ladder (medium)	2	FA 2.4 – 2.4 m Forestry Ladder
Safety			
Chainsaw Chaps		4	Clogger Chainsaw Chaps - zipped
Helmet/Visor/Earmuffs		4	Protector Vented Helmet Complete
Steel cap boots	slip on (no laces- trip hazard)	4	e.g. DeWalt Wheat Radial Steel Toe Boot

Figure 23. DAFF Forestry Section taking delivery of new equipment.

9 Conclusion and recommendations

It is understandable that landowners are not enthusiastic about managing existing mahogany or toona plantations or establishing new ones, because of the long rotation, lack of intermediate returns, and no identified market.

With the ease of importing pine, cut to size, and treated for fungal and insect attack, from New Zealand it is unlikely that mahogany will replace pine in the foreseeable future. Instead, new markets for Niuean mahogany could be developed on the island.

Forestry staff are trained and equipped to help landowners and communities with tree plantation management and development of other tree crops using the principles developed for mahogany.

Sandalwood, combined with a productive host tree, offers a potential pathway to a forest tree crop with a shorter maturity period and income. This may interest landowners more than mahogany.

9.1 Recommendations

- The small forest section opposite the Vaipapahi Agricultural Farm should have a few seedlings on hand at all times to either sell or give away to encourage farmers and landowners to plant trees.
- The demonstration forest stand and sandalwood trial should be maintained in accordance with schedules and training set out in this report and the video.
- Sandalwood seed should be collected, germinated, grown in bags, and trialled with likely host plants, including noni and *Tipolo Iapani* imported from the closest source – Samoa (DAFF bio-security permitting).
- The video should be made available for viewing by transferring copies to other government departments and individuals with computer access and should be screened regularly by DAFF.

10 References.

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