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Final report

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2 Executive summary

Vanuatu is currently in a period of transition from harvesting native forests to developing plantation resources. One of the most promising species, native to Vanuatu and neighbouring countries, is *Endospermum medullosum*, or whitewood. This project had as its basic objectives the development of a set of silvicultural guidelines for whitewood, for small woodlots and larger-scale plantations, and preliminary assessment of the wood qualities of plantation-grown whitewood.

The project team interviewed 139 landholders in 2008. They found that, in spite of many years of promotion of whitewood as a viable plantation species only 63 ha had been planted in the three major regions of Espiritu Santo Island, though Melcoffee Sawmills has one 17-year old plantation of 270 ha. The primary reason for this failure of plantation establishment is the lack of clearly defined markets for whitewood trees. Many small woodlots were planted but the landholders interviewed had little confidence that planting larger areas would be a profitable activity.

The 230 woodlot plantations on Espiritu Santo range up to 20 years in age and provide a guide to the expected growth rates of whitewood in plantation in those areas. Soil and land characteristics were described at more than 40 of these plantations. Growth plots 0.05 ha^2 in size were set up in 28 of those sites and measured over four years. These plots indicated mean growth rates of whitewood of approximately $20m^3$/ha/yr at age 17. Using soil and site assessments and resource mapping it was estimated that around 33 000 ha of land on Espiritu Santo is highly suitable for sustainable whitewood development and is currently not intensively utilised or in native forest.

Soils on Espiritu Santo are highly fertile and productive but there is strong competition with planted trees from the exotic vine *Merremia peltata.* In a trial comparing plots that were ripped with ones that were not, no difference was recorded in whitewood survival or growth. Further, fertilizer trials on the Lorum site indicated no significant difference in growth of seedlings with fertilizer treatments. Therefore using bulldozers to drive over weeds without major soil disturbance, whilst leaving plant material on the surface, and not using fertiliser can be recommended for large-scale projects.

To test the impact of tree spacing on growth and branch development 15 hectares of spacing and thinning trials were established across Espiritu Santo. Two and one half years after thinning significant differences were observed between thinned and un-thinned trees: the annual diameter increment of retained crop trees was 5.6 cm in the thinned plots compared with only 3.5 cm in the un-thinned plots. Recommended density of trees depends on objectives, including whether the landholder is exclusively growing timber or also gardening between rows of trees. The project developed a 50-page silviculture manual which provides guidance on the establishment and management of whitewood plantations.

Mixtures of tree species spread the risk of destruction by pests or diseases and can support higher biodiversity than pure monocultures. Two native species were chosen: *Flueggea flexuosa*, namamau, and *Terminalia catappa*, natapoa. Nineteen months after planting these two species combined with whitewood had comparable heights and diameters. The durable species *F. flexuosa* can be harvested after 3-8 years and used for roundwood; whitewood reaches sawlog size in 15-20 years and natapoa can be left to grow on, not only to produce higher quality sawn timber after 25-40 years, but also for continued nut production.

Sampled logs from a 17-year old plantation indicated a high percentage (65%) of knotty wood and identified opportunities to add-value to knotty wood by preparing long structural boards and cutting clear sections between defects. An analysis of the value-chain for domestic and export markets and of opportunities for value-adding is being completed as part of an ACIAR-sponsored Masters degree at SCU, by Rexon Viranamangga.

3 Background

Almost 7% of forests worldwide, some 271 million ha, are industrial plantations (Carle et al. 2009). These forests are increasingly important to ensure supply of the world's demand for wood, but the current estate is based on a few species and narrow genetic base. The lack of diversity in planted forests currently exposes the global timber industry to risks, particularly from pests and disease (Nichols et al. 2006). Amongst several thousand tree species in the world only about 30 have been extensively planted. Although holding great potential, few native species found in rainforests have begun to be "domesticated" in plantations (Nichols and Vanclay 2012). The tropical species, from small island nations like Vanuatu, offer special opportunities and challenges to help develop a timber resource based on tree species that are well adapted to local conditions.

Whitewood (*Endospermum medullosum*) has been an important commercial timber species from native forest that was exploited throughout the English-French colonial period in Vanuatu and after independence in 1980. As a result, the most accessible whitewood resource has been extensively depleted (Viji et al. 2001) and the commercial timber industry has largely ceased in Vanuatu (Viranamangga et al. 2012). Whitewood has been identified by researchers and the Vanuatu Government as a high priority species (Walker 1996, Viji et al. 2001). The aim of this project was to develop comprehensive silvicultural prescriptions for the establishment of whitewood plantations.

Whitewood has shown to be a productive and useful species in a variety of situations, including small woodlots where trees are incorporated into traditional agroforestry gardens as well as larger "industrial" style plantations. The prescriptions for deployment of whitewood in plantation and agroforestry systems need to be tailored to suit different community and landholder needs. Well developed silvicultural prescriptions will help to ensure production of whitewood succeeds in terms of increased volume of wood, improvements in wood quality and environmental benefits (soil, water and biodiversity improvements) for Vanuatu. The goal of a domestication program is to clearly identify silvicultural prescriptions and identify markets. The current demand for wood is approximately 3.6 billion m^3 annually (Carle et al. 2009), and demand is predicted to increase as populations grow and the major centres in Asia develop. Vanuatu is well placed to contribute to global wood supply, particularly given the favourable climate and fertile soils.

In 2003, timber exports of whitewood represented 14.5% of total exports, by 2008 timbers share of total export earnings had fallen to 2.5% (McGregor and McGregor 2010). As a result of diminishing wood supply, Vanuatu is currently heavily dependent on imports of wood products (Vutilolo et al. 2005, 2008); this situation has led the development of whitewood as a plantation species (Thompson 2006). Despite the dramatic downturn in forest industries in recent years (due to the "global financial crisis"), Vanuatu has displayed a strong local demand for wood and has some important processing infrastructure and industry development in place (Viranamangga et al. 2012). A small private commercial scale plantation, of approximately 270 hectares, and an associated processing infrastructure presently exist and demonstrate that planted whitewood can be harvested in less than 20 years. Community-based plantings of whitewood have also expanded somewhat during the past decade and the existing infrastructure provides the basis for developing a market for the product. A significant amount of genetic improvement, improved seed and propagation research has already been carried out under the South Pacific Regional Initiative on Forest Genetics (SPRIG) Phase 1 and Phase 2 projects and is continuing in the ACIAR project FST/2008/010.

The development of a community based or medium scale plantation industry based on whitewood will provide some significant challenges. Little research had been undertaken, prior to this project, in the areas of establishment silviculture and stand management. To develop a viable and productive industry, a set of clear prescriptions has to be available to landowners. Thomson (2006) made a series of recommendations, which have proved to be valuable for early efforts to grow whitewood; this project has tested those prescriptions quantitatively to clearly demonstrate the importance of appropriate silviculture for producing high value wood. At the time the project started, the current plantation practices were extremely variable, seriously reducing the uniformity of the resource and therefore reducing potential economic returns to landholders. The variability in the resource is also a problem preventing the development of a more substantial export market and sophisticated processing industry.

Figure 1 Degraded land in Santo (left) that can be converted to productive plantations (right) ready for harvest in less than 20 years.

The government of Vanuatu has stated that a seven-fold increase in the plantation estate is a priority over the next 18 years to 20,000 hectares (Department of Forests 2011). The drive for self sufficiency and potential for exports provides the opportunity to develop international investor interest in a whitewood plantation industry in Vanuatu. Properly developed, the industry associated with such a plantation estate could have an annual export value approaching US$50 million per year based on the existing market and current world prices and trends over a 20 year period. One of the most important technical impediments to realising this economic opportunity is the absence of well considered silvicultural prescriptions that will optimise productivity, log quality and product value.

The development of silvicultural prescriptions in this project involved assessing: site characteristics (including development of a land suitability assessment system), establishment of experiments to test the efficacy of site preparation, weed control, spacing and thinning and examination of spacing effects in existing plantings. Whitewood growth was evaluated in monoculture (in existing plantations and new plantings) and mixed plantings of whitewood mixed with the indigenous species *Flueggea flexuosa* (Namamau) and *Terminalia catappa* (Natapoa). Agroforestry systems with whitewood mixed with taro, cassava and kava were also established to demonstrate plantings that provide short term income.

The wood from planted trees is often quite different from that of mature trees from natural forests (Bootle 1983). The extent to which young whitewood grown in plantations varies from the wood sawn from natural forests was not known. Wood quality and wood characteristics of whitewood were investigated in this project to inform basic productivity and yield models, and financial analyses. Re-measure and sample collection from older experiments provided some important long term information that was incorporated into a new silvicultural manual and scientific publications on variation in wood properties and potential wood products. The development of large areas of productive plantation will require that landholders, extension officers and policy makers have a good understanding of the land available and the best methods of growing trees and processing timber, given the scale of the resource.

4 Objectives

The major aim of this project was to develop comprehensive silvicultural prescriptions for whitewood plantations in a variety of situations, including small woodlots where trees are incorporated into traditional agroforestry gardens, as well as larger industrial style plantations. Further, the project aimed at a preliminary investigation of the wood properties of whitewood and of opportunities for value-adding.

The project had the following specific objectives:

Objective 1: To identify site selection criteria, and characterise site availability in Santo

Objective 2: To define appropriate establishment silviculture prescriptions

Objective 3: To define stand management systems that optimise economic returns (through manipulation of both productivity and wood quality, tree species mixtures and agroforestry combinations)

5 Methodology

Objective 1. Soils and site assessment

The landholder surveys conducted by the project team were informed by the database developed by DoF and Melcoffee Sawmill that generated a list of some 139 landholders in three regions of Santo. The multi-institutional investigators (DoF, SCU, VAC) visited all of these stakeholders and conducted interviews focussing on their existing whitewood plantings and intentions for future plantation establishment. A mixed-method approach, combining quantitative and qualitative methods was used (Aru et al. 2012).

Existing databases at the Department of Forests Vanuatu (DoF) listed some 230 whitewood plantations across Santo Island. A subset of 40 sites was selected throughout southern, central and northern parts of east Santo. Mapping data used for the project was derived from the Vanuatu Resource Information System (VANRIS), developed by a team of scientists from the CSIRO (Division of Tropical Crops and Pastures, Brisbane Australia) in collaboration with the Queensland Forest Service and the Vanuatu Department of Forestry in 1990 (Bellamy 1993). VANRIS provided detailed spatially-based information for all of Vanuatu. This data was integral to the mapping of land suitable for whitewood plantations.

Land suitability assessments included descriptions of soil and site characteristics at representative points within the selected plantations. Soil samples from auger cores and/or pits were used to determine texture and nutrient status (National Committee on Soil and Terrain 2009). Soil scientist John Grant coordinated the preparation of 40 soil pits on Santo, providing the opportunity for training of DoF crews in the basic procedures of field soil description. Soil was described to a depth of 110cm or to the coral parent material, and tested chemically for the presence of allophanic clays, which fix phosphorous and make it unavailable to plants. Photos of all soil profiles are included in the Permanent Sample Plot (PSP) database. AYAD volunteer Bronnie Grieve developed an Access database for all project trials and trained project staff in its use.

The initial data set from 40 soil pits was used to select 27 sites, based on observed variation in terms of north-south spread of locations, to provide representative samples across variations in altitude and topography. Growth plots were established and the whitewood productivity data was correlated against soil and land characteristics. This data was used to develop a growth model to predict yields of whitewood (more detail on growth and yield is presented in Results Section 6.3).

Objective 2. To define appropriate establishment silviculture prescriptions

To test the influence of site establishment techniques on growth across a range of conditions, some 15 ha of trials were established at various locations on Espiritu Santo Island (Figure 1). The main site for testing establishment (site preparation, weed control, fertiliser) options was at Lorum, where a 5 ha trial instituted by Dr Geoff Smith, who was research officer with Forests NSW at the time. This large trial was particularly focussed on tree spacing, use of heavy equipment in site preparation, including ripping of rows, on weed control and fertiliser options. One spacing trial was established at Kalsei farm, adjacent to the large Lorum plantation; and another spacing trial at the property of Victor Andre northwest of Luganville. Spacing trials established in 1995 by Queensland Forestry Research Institute were remeasured. After considering many options for species to combine with whitewood in mixtures, replicated trials of whitewood with two other native species, namamau (*Flueggea flexuosa*) and natapoa (*Terminalia catappa*) were planted with long-time landowner collaborator Mr. Malakai. A demonstration planting of the same mixture was established at Jubillee Farms, a site close to Luganville and Vanuatu Agriculture College, and therefore convenient for field days.

Thinning trials were established at Victor Andre's site at Belaru in the period from late 2007 to early 2008. The entire woodlot was planted at 4x3m spacing (833 stems/ha) at establishment. At about 2.8 yrs old, 6 plots were thinned to 417 stems/ha and 6 plots were retained at the original spacing (833 stems/ha). The trial was thinned at this age as the tree canopies had achieved "site capture", and competition between trees can begin to exert an influence on diameter growth on individual trees at this stage (West 2006). After thinning measurements were carried out every six months to look at the impact of thinning on the growth and canopy characteristics the diameter, height, basal area and branch size in the first 4m of the stem was measured just over a year later, when the trees were 4 years old to assess the impacts of thinning on young whitewood.

At Loro and the Kelsai sites a set of spacing trials have been established in 2007 and 2008 that will be thinned in 2012 by the DoF Forestry personnel. The thinning trials at Kelsai will be carried out on whitewood planted at 6x3m and 8x3m spacings.

The Lorum trial site is located at Shark Bay in north east Santo Island. It is a large contiguous area largely covered in *Merremia peltata*, with few woody vegetation remnants or other weeds. The intention was that lines would be cleared by bulldozer but the presence of interconnecting vines meant that much of the site was almost completely cleared and windrowed. The site was cleared by bulldozer and trials were laid out and plots marked in September, and planted in October 2008. A total of thirty plots were established, each 32 m long on one side and varying from 30 to 45 m in length on the other sides (Appendix 4). To assess the effect of ripping, two plots (32 by 45 metres) were ripped, to compare with two adjacent unripped plots, which were cleared by bulldozer. A large silvicultural regime trial was established with 8 plots each of 4 x 3, 8 x 2 and 8 x 3 m spacing of whitewood seedlings. The high number of replicate plots allows for later thinning treatments. A small plot fertiliser x weed control experiment consisted of 4 replicate blocks (24 x 32 m) of 4 plots at 4 x 2 spacing. Weeding began two weeks after planting and continued at intervals of several weeks for two years. Infill planting necessary due to mortality (thought to be caused by high temperatures on exposed black soil) was undertaken in December 2008 using the same batch of plants that had been grown on in the nursery after being transferred into larger pots.

Fertiliser treatments were applied in late January 2009. Only one general purpose fertiliser was available locally, Crop King, which is 12%N, 12%P, 17% K + 2.5% Mg + 0.3%B. The treatments were: control, single dose (NPK in Appendix 4 table), NPK+ which is a single dose plus micronutrients, double NPK, double NPK plus micronutrients and trple NPK plus micronutrients. Crop King applied at 50gm per tree was the single fertiliser treatment, which provides 6g P per tree, a rate that is broadly recommended for plantations. Micronutrients were applied as 0.23gm elemental Zn (as zinc sulphate heptahydrate) and 0.06g of elemental B (as borate) per tree (plus the additional B in the Crop King). The double treatment used two times the Crop King rate, with or without the micronutrient. Fertiliser was applied on the soil surface 15cm from the base of the tree on the downhill side after infill planting took place. The trial used a complete randomised design with 4 replicates of each treatment.

The fertiliser by weeding trial had a factorial combination of fertiliser and weeding treatments; either NPK+ or triple NPK+ and a one-metre diameter circle around each tree cleared with a bush knife or sprayed with glyphosate. (Smith et al. (2012) contains a literature review of establishment techniques used in tropical plantations, with the results from the Lorum trials presented there and in Results Section 6.4).

In addition to the 5 ha experimental site at Lorum, spacing/thinning trials were established, adjacent to the Lorum trials, at a site called Kelsai, at Shark Bay. Spacing/thinning trials were also established at Victor Andre's farm in central Santo. Long-term growth data was also collected from spacing trials put in by Queensland Forestry Research Institute in 1995 at Loro (Table 1). Demonstration plots incorporating whitewood into agroforestry gardens and coconut plantations and mixing whitewood with *Terminalia catappa* and *Flueggea flexuosa* were planted at Jubilee Farms, near Luganville.

In the popular environmentalist press there are often calls for planting more mixtures of trees, as opposed to "monocultures" (Nichols et al. 2006). One of the challenges foresters face is specifically how to design mixtures, the particular combinations in time and space, to employ. This challenge is reflected in the difficulty of designing experiments to test the interactions of different species in planted mixtures (Vanclay 2006).

At the Malakai farm site, a mixed-species plantation trial was established in 2008. Eight plots were planted, four of pure whitewood and four with mixtures of whitewood, namamau (*Flueggea flexuosa*) and natapoa (*Terminalia catappa*). The mixed species agroforestry trial was established using species such as namamau, that have the potential to generate shorter term benefits from harvest of small poles and fencing from young trees (5-7yrs old trees) that can be used within the local community. The removal of the namamou potentially represents a commercial thinning opportunity that will leave more space for the development of the larger timber species. Whitewood represents an intermediate timber harvest (at 15- 20 years) for local or export. The Natapoa represents a longer rotation (25-35 yrs) high value hardwood species for export or use locally where wood colour and figure may command a market premium to growers.

All trees were planted in rows 8 metres apart. Whitewood in pure stands was planted at 3 m apart within rows, representing a common spacing (8mx3m) in whitewood plantings. In the mixed plantings the other two species alternated with whitewood, at 2 m between trees within rows. There were two buffer rows of whitewood around all measurement plots. A total of 120 whitewood were planted in the centre measurement plots in the monocultures. A total of 60 natapoa, 120 namamau, along with 60 whitewood were in the core measure plots of the mixtures. This spacing represents a stocking of 8x4m for namamau, and 8x8m for both natapoa and whitewood in the mixed plots. The objective of this trial is to compare and demonstrate the costs and benefits of a multi-species agroforestry system (625 stems per hectare, initial spacing) with the common whitewood, single species spacing of 417 stems per hectare. It is anticipated that at aged 5-7 years that the removal of the nanamou and some of the poorer quality whitewood and natapoa will lead to a retention of approximately 250 stems per hectare of large timber trees in both the single species and mixed species plots.

Table 1. Summary of spacing/thinning trials.

Trial	Victor	Kelsai	Jubilee Farm	Lorum	Loro [1].
Location	Central Santo	Shark Bay	Luganville	Shark Bay	Shark Bay
Plant Date	Feb 2008	Mar 2008	Apr 2008	Oct 2008	1995
Previous land use	Garden	Garden	Coconut, garden	Bush	
Area (spacing)	0.5	2 × 1 ha	0.5	2.5	1.5
Spacings – m	4 × 3, 4 x 6	8 × 3; 6 × 3	8 × 6	4 × 3; 4 × 4; 8 × 3.	2 × 4; 2 × 6; 2 × 8; 2 × 10; 4 × 4; 4 × 6; 4 × 8; 4 × 10; 6 × 6; 6 × 8; 6 × 10.
Replications	6	0	0	8	2
Treatments	Unthinned, Thinned to 415 tph @ age 2.8.	(8 × 3) garden for 2 years		To be thinned	Variable plot size
Design*	RCB			RCB	RCB
Measurements	DBH, branch, stem quality		DBH	DBH, Ht age 1, 2, 3	DBh, Ht age 2,4,9.

1. planted by QFRI staff 1995 (Walker and Haines 1996). * RCB = randomised complete block

Objective 3. Define silvicultural systems that optimise economic returns

Growth modelling

Permanent Sample Plots 0.05 ha in size were established in 27 whitewood woodlots throughout Santo during 2008. These were measured annually over the next three years. Three simple relationships summarizing stand dynamics, namely height-age, diameter-height-stocking, and mortality-basal area relationships, were calibrated with data from 17 plots to form the basis of a model for silvicultural and management decisions. The components of this simulation model are: a growth model to predict stand dynamics, mensurational relationships to infer total and merchantable volume, and some financial tools for basic economic analysis.

The growth model relies on three equations that estimate height (H, equation 1), diameter (D, 2), and self-thinning relationships (3):

$$H = \beta_1(t-0.5)^{0.5} \qquad [1]$$

$$D = \beta_2(H-1.3)/lnN \qquad [2]$$

$dN/N = -2(G/ Gmax)^3 dD/D$ [3]

Where t is age (years), H is top height (m), N is stocking (stems/ha), D is diameter (mean dbh over bark, cm), G is the observed stand basal area (m2/ha), and Gmax is the maximum carrying capacity of the site (m2/ha).

These three relationships are of interest because they are robust in data-poor situations, are easy to calibrate, and are safe to extrapolate, but it is emphasised that these offer reliable approximations rather than the precise estimates obtainable from more sophisticated site-specific models. Each of these three relationships relies on a single estimated parameter, a design feature that aligns with biology, and that confers robustness despite limited data. These relationships, account for the main plant dynamics that occur within monospecific plantings, and rely on stand-level data that is routinely gathered for forest monitoring and management.

Results Section 6.3 and the manuscript by Grant et al. (2012b) project growth across a broad range of spacings and rotation lengths for whitewood, based on data from selected plots (Table 2).

Table 2. Summary of selected plot data.

Plot No	Year planted	Spacing (m)	Nominal initial stocking	No of trees in plot 2008		Whitewood mean dbh (cm)		Top height 2010	Basal area 2010	Eqn 1 β_1	Eqn 2 β_2
				All	WWD*	2008	2010				
1	1994	5 x 5	400	23	22	32	33	22	36	5.5	9.7
3	1998	8 x 3	417	22	22	26	28	25	30	6.7	7.7
4	1998	8 x 3	417	20	20	25	28	19	24	5.2	9.7
5	1995	5 x 5	400	13	13	32	35	20	25	5.1	10.3
6	2001	3 x 3	1111	50	49	15	17	16	23	5.0	8.7
7	2004	3 x 4	833	18	18	12	22	16	14	5.8	9.1
12	1995	5 x 5	400	13	12	34	37	24	26	5.8	9.7
13	1993	2 x 2	2500	42	35	27	29	26	50	6.0	8.3
14	1996	4 x 4	625	20	19	27	31	23	29	6.0	8.7
17	1998	5 x 5	400	19	17	29	31	24	27	6.8	8.4
22	1998	6 x 2	833	16	16	25	28	21	10	5.5	9.9
24	1993	6 x 10	167	12	12	37	39	23	29	5.3	10.7
25	1997	5 x 5	400	25	22	27	29	22	33	5.8	9.0
26	1998	5 x 10	200	8	8	32	35	20	16	5.4	9.7
27	1995	10 x 5	200	13	11	44	46	23	37	5.9	11.6
Average		4 x 4	620	21	20	26	29	22	27	5.7	9.4

WWD*- Whitewood

Wood properties.

Six whitewood trees were selected in a 16-year-old plantation established by the Melcoffee Sawmill Company at Lorum on the south east coast of Santo Island. This plantation had been established at wide spacing (10m × 4m) and manually pruned to approximately 6m. The six trees, chosen to sample the range in diameter at breast height of the stand, were felled and cross cut in the forest to maximize the yield of straight logs and then transported by road to the Melcoffee sawmill. The average small end diameter of logs was 29.0cm (range19.2-42.8 cm). The logs were sawn to produce 25mm boards from the outer clear wood sections, and 50mm thick random width boards from the knotty, pith-included core, using a primary break-down band saw and a secondary circular rip saw.

A random sub sample of 30 boards, nominally 100×50 mm was selected from the sawn timber and tested for strength and stiffness in bending. Sample selection and tests were conducted according to the specifications in Australian and New Zealand standard AS/NZS 4063:1992 ***Timber - Stress-graded - In-grade strength and stiffness evaluation***.

Structural grade specifications are determined by the weaker timber in any sample to ensure the whole batch meets the minimum requirement. The aforementioned standard uses the 5th percentile ranked value for various mechanical properties of a population, which is further scaled to account for a safety factor. This means that culling the weakest pieces from a batch of wood increases the overall grade, so the trial examined potential for such culling of whitewood sawn wood. Each board was visually sorted into 4 structural grades, defined as (1) clear wood, (2) boards with small knots (<50mm diameter) only, (3) boards with large knots (>50mm), and (4) boards with included pith.

For preservative treatments, samples of sawn (4 pieces of 100mm × 100mm) and round (2 pieces >100mm diameter) whitewood were selected from different trees and transported to Australia where they were pressure vacuum treated with Koppers Tanalith E. in the Southern Cross University research facility. The ends of each sample were coated with a sealant prior to treatment. Penetration of preservative was assessed qualitatively on cross cut sections after treatment.

6 Achievements against activities and outputs/milestones

5.1 Schedule

Objective/ Activities	**Tasks**	**Time line (Yr - m)**	**Milestones Status as of 02/11/2012**
Obj 1: To identify site[1] selection criteria, and characterise site availability in Santo			
1.1 Describe the land available for potential future plantation establishment and assess the spread of existing plantation across land types	Stratify the area into land units[2] to produce maps using the data from VANRIS	Yr 1, m1-3	"Series of monitoring plots established" **Done: 27 Permanent Sample Plots established and measured annually since late 2007**
	Assess the range of sites incorporated within relevant land units	Yr 1, m1-3	
	Determine the extent of whitewood establishment across the range of land units and sites	Yr 1, m4-5	"New refined data set on growth produced" **Done. Used in Grant et al 2012a and 2012b in IFR special issue. See Results 6.2, 6.3**
	Test the maps' predictive ability based on site assessments in the field	Yr 1, m4-5	"Yield tables produced" **Done. Part of article by Grant et al 2012a and 2012b in IFR special issue. Across most of 53,000 ha area, expect MAI of 20 through year 17. Also in Results 6.3**
	Determine the extent to which the available experimental sites will be useful predictors for the potential estate as a whole	Yr 1, m4-5	

Objective/ Activities	Tasks	Time line (Yr - m)	Milestones Status as of 02/11/2012
1.2 Gain estimates of yield in community woodlots and large-scale plantings. Relate yields to site qualities and silvicultural management and produce a site suitability assessment system[3-]	Establish yield plots in woodlots representing as many of the soil/site types as possible Remeasure in year four of the project Determine growth rates and relate to site characteristics and use to determine predictive usefulness of experimental sites	Yr 1, m4-6 Yr4, m4-6 Ongoing throughout project Yr4, m7-10	**Estimated yields (MAI of 20 to 17 years on average sites). Site suitability map is Figure 12 in Silviculture Manual. Grant et al. (2012 a and b)** **Results 6.3**
1.3 Train Vanuatu personnel in use of site assessment method for judging suitability for whitewood	Training sessions	Yr 2, m 2-5 Yr 4 m 7-10	"Personnel capacitated in assessing sites and planting whitewood only where good production expected" **Done – John Grant led teams primarily from DoF Vanuatu but also Melcoffee Sawmills, and Vanuatu Agriculture College in digging 40 soil pits, with soil photographed, taken to lab for analysis. A subset of these became the 27 PSPs and a subset of 17 of these was basis for model (Grant et al 2012a &b). Results 6.2**

[1] Where site is defined as an area that is relatively homogeneous in soil, climate, parent material and topography and requires homogeneous silviculture management for sustainable production.
[2] Where land unit is defined broadly in terms of the available data (from VANRIS) that is relevant to plantation growth and management. The resolution of that stratification will be determined by the detail included in the primary data.
[3] A site suitability assessment system allows classification of sites in terms of their potential productivity (and limits to productivity, particularly where these limitations may be ameliorated) and their suitability (which includes productivity along with a wider range of considerations such as management requirement and degradation potential).

Activity 1.1

Using the VANRIS data base and a series of 40 soil and site assessments, Grant and team identified 77 911 ha of land suitable for whitewood plantations on Espiritu Santo Island. Of this area they estimated that around 33 000 ha of land on Espiritu Santo is highly suitable for whitewood development and is currently not intensively utilised or in native forest (Grant et al. 2012a)

Using Department of Forests data, Mr Rodney Aru of this project and now forestry lecturer at Vanuatu Agriculture College, led a team who interviewed 139 landholders. Their findings are summarized in Results Section 6.1 and in Aru et al. (2012). Somewhat surprisingly, in spite of clear rapid growth rates of whitewood, the giving away of some 200,000 seedlings by DoF and Melcoffee Sawmills, as well as promotion and extension activities, only 63 hectares of whitewood woodlots were verified as having been established. This does not include one larger scale plantation of Melcoffee, the 17-year old stand of 270 ha at Loro.

Activity 1.2

The project established 27 Permanent Sample Plots (PSP) in late 2007 and early 2008. These were then remeasured annually from 2008 through to 2011. Across the PSPs, whitewood growth in Mean Annual Increment was estimated at 20m3 /ha/yr to 17 years of age (Grant et al. 2012b). Mean tree diameter was highly influenced by stocking level, with the average diameter at low stocking (<300 trees per ha) being ~42cm at age 17, ranging down to 28cm at higher stockings (>500 trees per ha). These results, from the PSPs were again confirmed in the various spacing and thinning trials (results Section 6.5) established elsewhere by the project and listed in Table 1, and discussed in Glencross et al. 2012.

Activity 1.3

Training in whitewood site selection was done in the process of putting in 40 soil pits and establishing and maintaining 27 Permanent Sample Plots. Officers from the Department of Forests were involved in digging soil pits and performing field analyses with soil scientist John Grant (see Results Section 6.2). DoF workers as well as DoF trainees, students from the Vanuatu Agriculture College forestry program and two volunteers from AYAD assisted in putting in the PSPs and measuring them over the life of the project. The PSPs were used as an example in mapping exercises using Geographic Information Systems, taught by Ms Therese Moffat of Southern Cross University.

Objective/ Activities	Tasks	Time line (Yr - m)	Milestones Status as of 02/11/2012
Obj 2: To define appropriate establishment silviculture prescriptions.			
2.1 Identify experimental sites and prepare them for implementation of treatments	• Available sites identified that represent Industry, Community and Government input and collaboration. • Detailed experimental working plans completed to take into account the site characteristics and availability of equipment, machinery and labour.	Yr1, m1-3 Yr2, m2-5	"Stakeholders representing the three types of land tenure have experimental plots on their land and are participating in program." "Permanent Sample Plots in place" **Total of approx. 15 ha of trials established, in addition to PSPs. Major locations include Lorum (5 ha trial) Kalsei, Victor Andre, Malakai, Jubilee Farms (Fig. 1, Table 1)**
2.3 Prepare planting stock	• Improved seed to be collected • Nursery system upgraded, resources acquired and seedlings raised by Month 5 for start of planting season at Melcoffee Sawmills Limited nursery	Yr 1. 3m Yr 1. M3-m5	"Improved seed collected from Seed Orchard ensuring use of best available genetic material". **All stakeholder groups are involved with plant production and the links between DoF and MSL were strengthened through this collaboration at project commencement.**
2.4 Interpret final data and prepare prescriptions	• 3 year growth response data are analysed to quantify both yield implications and economic implications of imposing one or more of the establishment treatments	Yr 4. M7-m10.	"Research results are presented as prescriptions, available in the form of a silvicultural manual. Landholders and investors are able to determine the likely product and economic impacts of imposing treatments." **Done, see "Silviculture of whitewood in Vanuatu" by Kevin Glencross and Rexon Viranamangga, Appendix 2**
2.5 Prepare extension material and implement technology transfer strategy	• Posters designed and prepared. prescriptions written	Yr 4. M7-10	**Done, whitewood brochure (Appendix 5) and posters (Appendix 3 and 4) included in appendices**

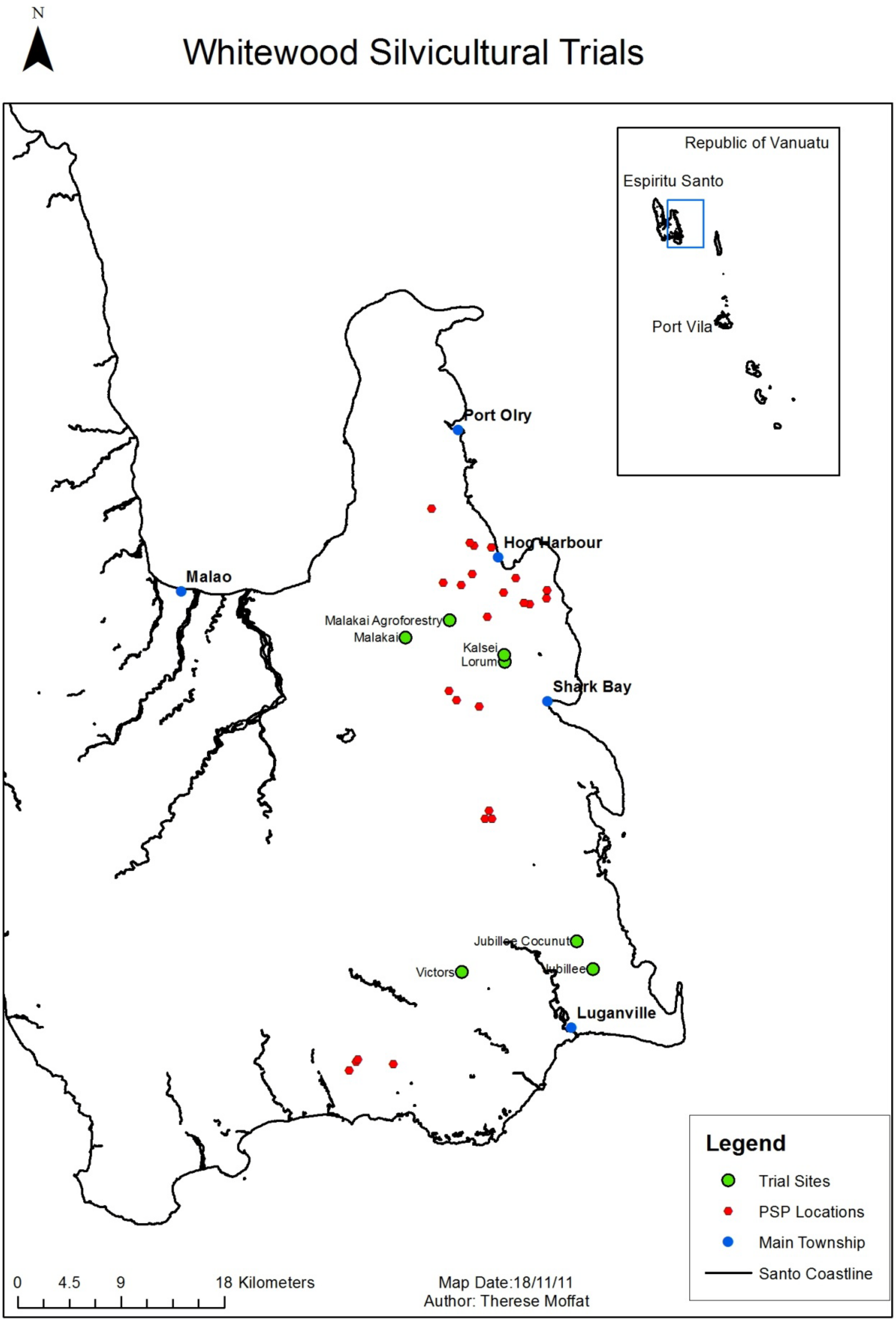


Figure 1. Location of silvicultural trials and Permanent Sample Plots (PSPs) on Santo Island.

Activity 2.1

Approximately 15 ha of trials were established, in addition to 27 Permanent Sample Plots (0.1 ha each) (Figure 1). The largest experimental site is at Lorum and includes 5 ha of experimental plantings on site preparation, weed control, fertilization, spacing – results are summarized in Smith et al. (2012) and in Results Section 6.4. There are trials (Table 1) at farms of:

Victor Andre, long-term collaborator – spacing, thinning and pruning and agroforestry combinations, especially with peanuts.

Malakai – spacing and mixtures with natapoa and namamau

Kelsai – spacing trials adjacent to Lorum

Demonstration plots at Jubilee farms – whitewood with coconuts and agroforestry gardens, and with natapoa and namamau

In the process of identifying sites to be used for project experiments, a great deal of time was spent "networking" with various individuals and institutions in Vanuatu, particularly throughout Espiritu Santo. There appeared to be great opportunities for collaboration with VARTC, the French-government sponsored agricultural research organisation, which has an office next to the DoF in Port Vila and maintains a field station on Espiritu Santo a short distance north of Luganville, close to Vanuatu Agriculture College. For this project no trials were planted in cooperation with VARTC but the possibility should be kept in mind for future work, as the combining of trees and agriculture in Vanuatu has great potential.

Activity 2.2

With the presence of *Merremia peltata* at all sites, it was necessary to perform manual weed control every two weeks throughout the first two years after planting and then monthly in the third and fourth years. Permanent Sample Plots were measured annually. Silvicultural trials were measured twice per year, in November/December and then after the wet season, in March/April.

Activity 2.3

Planting stock in some experiments was from 1998-99 seed orchard established by SPRIG project. Thus as trials mature they can be added to the estate of high-quality seed production. Further seed orchards are being established in 2012 by FST/2008/010 under Dr Tony Page of JCU, on Efate and Santo. Planting stock was also obtained from both Melcoffee Sawmills and Department of Forests nurseries.

Activity 2.4

Final data from the four years of this project has been summarized in a series of seven articles for a special issue of International Forestry Review, guest edited by Jerry Vanclay and Doland Nichols, plus two done in collaboration with FST/2008/010, listed under "publications produced by this project". Further the data informed the development of extension materials and the Silviculture Manual (Appendixes 2-5).

This data should not be considered "final" but "interim" in the long term, that it forms part of a support network of information useful for a plantation-based industry and that the work done by this project can be built upon by subsequent ACIAR projects, the Department of Forests, landholders, community groups, Vanuatu Agriculture College, VARTC and other interested stakeholders.

Activity 2.5

For summary of extension activities, see "Capacity – workshops". In the appendices are examples of the posters produced by the project and disseminated throughout the islands by DoF Vanuatu. DoF Vanuatu will be able to use computer files and posters for years to come, in support of development of whitewood plantation sector.

Objective/ Activities	Tasks	Time line (Yr - m)	Milestones Status as of 02/11/2012
Obj 3: To define stand management systems that optimise economic returns (through manipulation of productivity and wood quality, tree species mixtures and agroforestry combinations).			
3.1 Address costs and benefits of thinning	Implement thinning treatments on existing community woodlots	Y1. m9 & Y3, m2	**Stands thinned at Malakai's (near Shark Bay), Victor Andre's (nw of Luganville) and Kelsai's (adjacent to Lorum) farms (see Sec. 6.5/6,8)**
3.2 Collect "improved" seed. Examine wood quality in young thinned trees	Thin seedling seed orchard to determine effects of later age intervention. Collect disks to assess basic density variation	Y1. m9-10	**SPRIG seed orchard thinned, seed collected for new seed orchards under FST/2008/010** **Wood quality from thinned trees presented in paper (**Doran et al 2012), **Section 6.7**
3.3 Determine spacing management prescriptions	Re-measure existing spacing trials at the MSL Loro site and review growth data.	Y4. m3-5	**Data collected from original 1995 spacing trial MSL Loro (Walker/Haines 1996); spacing trials at Victor Andres, Lorum and Kelsais. Preferred spacing options presented at five workshops, final conference field day. Included in silvicultural manual, posters and brochure.**
3.4 Consider the effects of improved silviculture and stand management on wood quality and wood products	Develop taper equations from both thinned material and existing older trees in the Loro estate	Y3. m1-4	**Activity complete**
3.4 continued	Assess wood quality (initially basic density) of fast grown trees at the putative reduced rotation age of 15 years, compare to younger and older material.	Y3. m1-4	**Activity complete**

Obj 3: To define stand management systems that optimise economic returns (through manipulation of both productivity and wood quality, tree species mixtures and agroforestry combinations).

A formal economic analysis was prepared by a consultant Dr Andrew McGregor (Appendix 1). Whitewood products from Vanuatu were compared with similar materials from other countries, with a particular focus on the market for mouldings in Japan. This report discussed the comparative advantages and disadvantages of Vanuatu whitewood in relation to the demands of the Japanese market, and alternate sources of finished products with similar properties.

Activity 3.1

Stands thinned at Malakai's (near Shark Bay), Victor Andre's (nw of Luganville) and Kelsai's (adjacent to Lorum) farms were measured to calculate benefit in diameter increment to remaining crop trees (Results 6.5 and Glencross et al 2012). The cost of thinning at age 3-4 years is fairly low, at $0/30-0.50 per tree, or $60 per ha for 150 trees. This is roughly the same cost as one manual weeding, which has to take place twice a month for first two years of a plantation, certainly where there is merremia. For larger trees requiring use of a chainsaw the cost per tree is approximately $0.75. The economic details of different thinning scenarios are also considered in developing a stand management model (Results 6.3 and Grant et al 2012b).

The project foresters and scientists found that, as in Australia, there is strong resistance to the idea of precommercial thinning or "thinning to waste", meaning a treatment after which trees are simply left on the ground, rather than being sold. A major objective of the many workshops and of much of the extension material was to convince plantation owners of the benefits of thinning. The idea of planting many stems to capture a site from competing vegetation but then later on eliminating some of those stems to the benefit of crop trees is something that is well known to foresters worldwide. Also it is a nearly universal experience of foresters that it is difficult to convince people to perform these treatments, particularly when there is no financial benefit in the short term.

Activity 3.2

Seed collected from the SPRIG whitewood seed orchard established in 1998-99 was used for some trial plantings as well as forming the basis for new seed orchards implemented by a related ACIAR project led by Tony Page. A study of wood quality in relation to families from Shark Bay seed orchard was the product of collaboration between this whitewood silviculture project (Results 6.7, Doran et al. 2012, Settle et al. 2012) and FST/2008/010, on improved germplasm of whitewood and sandal wood.

Activity 3.3

In the silvicultural treatments called "thinning" which include precommercial operations in which trees are felled on site, or later commercial operations in which trees are harvested and sold, the project was led by Dr Kevin Glencross. At the same time he was working with whitewood prescriptions for thinning in Vanuatu he was leading a team examining the effects on growth and wood properties of thinning in plantations of *Eucalyptus dunnii* and *Corymbia citriodora* var. *variegata* in subtropical Australia (Glencross et al 2011).

The advantage of closer spacings, usually 4 x 3 metres, in whitewood, are that canopy closure occurs earlier than it does in spacings of 6 or 8 by 3 metres, the other major options, and that branch shedding is accelerated. The latter effect is important in lessening the need for pruning, which is time consuming anywhere and quite expensive in Australia.

Results 6.5 and a stand management paper (Glencross et al 2012) explain the results of thinning trials, whilst the Silviculture Manual for whitewood, by the same author, gives recommendations to whitewood plantation managers. As was expected crop trees in thinned stands began to have larger diameter increments than trees in unthinned stands. Also Glencross and others found there were clear correlations between number of branches and size of knots and density of planting. There were fewer live branches and mean branch diameter was smaller at higher stockings (Results 6.5 and 6.7 stand management and wood properties respectively and Glencross et al 2012).

Activity 3.4

Traditionally most wood in Vanuatu, as well as in the rest of the world, has been harvested from native forests. In the past several decades there has been a large shift toward plantations so that some 7% of the world's forest area, if in plantations, can potentially supply two-thirds of the wood used (Carle et al 2009). The same sort of potential exists in Vanuatu, where whitewood from accessible trees in native forests has mostly been removed and a plantation sector is slowly developing.

One of the great challenges in making this transition is in determining how to manage, harvest, and process the generally much smaller and more uniform logs coming from plantations. Glencross and Nichols (2005) reported variable wood properties of some Australian rainforest trees from native forest and plantation, particularly on *Elaeocarpus grandis* which is quite similar to whitewood. Tentative conclusions were that the properties of wood coming from plantation-grown trees were roughly comparable to those of trees from native rainforest. Dr Glencross took the lead on this project in assessing silviculture and wood properties of plantation-grown whitewood (Results 6.5, 6.7).

Dr Graeme Palmer, lecturer in Wood Science at SCU, supervised collection of logs from the Industrial Forest Plantation (IFP) and Loro (Melcoffee) (6 16-year old trees) plantations from thinned and unthinned stands. Merchantable volumes were estimated, as was taper. Thirty-five trees were cut and measurements taken at various positions along the stem during the whitewood project. A subset of trees has been used to generate a stem shape diagram (Figure 2) that shows the flaring at the base of the trees and the relatively low taper in the merchantable part of the stem from about 1.5m to 12 metres above the ground. Stiffness and strength (MoE MoR) data were calculated for 30 sawn pieces approx 100mm X 50mm each, with visual defect assessments. (Results 6.8 and Viranamangga et al. 2012). Glencross collected density data of samples taken from the Shark Bay seed orchard. This was used in the paper prepared by John Doran for International Forestry Review (Doran et al. 2012).

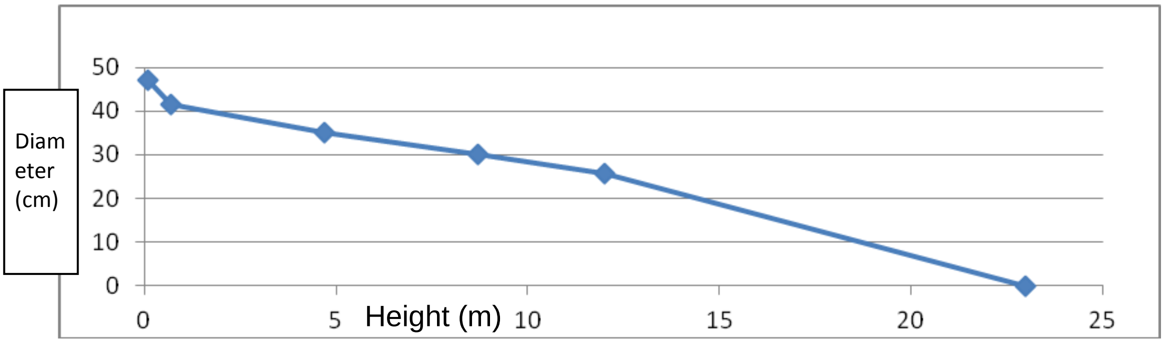


Figure 2 Stem taper diagram for whitewood tree harvested at 17 yrs old from Melcoffee plantation.

Palmer evaluated the penetration of preservatives into sawn wood pieces of whitewood with dimensions of 100mm X100mm. He presented results of these trials and discussed opportunities for use of small logs in his talks at the final conference. Tomker of DoF reported on yield of mouldings from small whitewood logs. An article on potential for value-adding with whitewood, by Viranamangga, Palmer and Glencross was accepted by the International Forestry Review.

7 Key results and discussion

7.1 Existing estate of whitewood and landholder survey

The Department of Forests Vanuatu had a database of woodlots that was lost in an office fire on Santo. Nevertheless it was known that there were some 230 small woodlots of whitewood on Santo. This project in 2008 embarked on a series of interviews of 139 landholders led by Mr Rodney Aru, formerly of DoF, at the time of surveys with this project and Melcoffee Sawmills and currently a lecturer in forestry at Vanuatu Agriculture College. He was assisted by Ms Kate Convery of AYAD and Southern Cross University and Mesek Sethy of DoF.

Surprisingly this survey indicated that, in spite of many years of promotion of the idea of planting whitewood, only 63 ha of whitewood had been established by the 139 landholders interviewed, who were located in south, central and east Santo. This does not include the one large plantation of 270 ha at Loro, established in 1994 by Melcoffee Sawmills. The number of hectares of whitewood planted, average area of plantations, and planned areas for expansion are listed by region of Santo in Table 3. The average area of plantation by the 88 landowners who had planted whitewood was found to be 0.7 ha. The survey also found that the landowners were willing to plant an additional 214 ha of whitewood, which if achieved would create a landowner whitewood resource of 277 ha equivalent to the single large plantation already established at Loro. More details of survey findings, including information on agroforestry combinations (Figure 11) used in whitewood woodlots and comments by landholders on technical details of their plantings as well as perspectives are found in a paper for International Forestry Review (Aru et al. 2012).

For the most part, landholders were not convinced that they could achieve a reasonable price for their trees and therefore had little enthusiasm for planting more whitewood.

TABLE 3. *Land areas planted and considered available for future planting to whitewood by land-holders surveyed on Santo Island, Vanuatu*

Region of Santo	Land-holders surveyed (no.)	Land-holders who grew whitewood (no.)	Land-holders willing to grow whitewood in the future (no.)	Whitewood area planted (total ha)	Average whitewood planted (ha/ land-holder who planted WW)	Additional arable land area available for plantations (total ha)	Land area land-holders willing to plant to whitewood (total ha)	Percentage of total additional area available that land-holders are willing to plant to whitewood (%)	Av. additional land area willing LHs prepared to plant to whitewood (ha/willing land-holder)
North-east	42	28	37	21.2	0.8 a	91	73	80	2.5 b
Central-east	46	34	42	31.4	1.0 a	173	77	45	4.7 d
South-east	51	26	51	10.8	0.4 a	152	64	42	3.0 bc
Totals	139	88	130	63.4	0.7	416	214	51	3.4

Note: For ‘a’ N=87, F=2.23, P=0.112 ; for ‘b-d’ N=128, F=3.23, P=0.043, sig. P<0.05.

7.2 Assessment of soils on Santo and estimation of area available for whitewood plantations

Samples of photographs of typical woodlots and associated soils are seen in Figure 3. The most common soil was a Hapludalf; the profile consisted of an average of 24cm (SD 9.8cm) of very dark brown (10YR2/2) to very dark greyish brown (10YR3/2) light clay to silty clay loam topsoil with strong fine granular structure. This graded into a 51cm thick (SD 20cm) dark yellowish brown (10YR3/4) to dark brown (7.5YR3/3) light clay to silty light medium clay subsoil with strong fine polyhedral to subangular blocky structure. These soils are described as having field textures of from clay loam to light medium clays but these soils are often subplastic (Bennett 1989). No particle size analysis was carried out, however it is likely that clay contents are much higher than indicated by the field textures. Similar soils from Santo have been reported as having measured clay contents of 70-80% (Claridge Undated).

Soils that were described within the plantations were relatively similar, with the main variation being total depth. Where the topography is dissected the soil depth was reduced but areas of shallow soils also occur on flat lying terrain. The sampled soils have excellent physical properties with good structure and drainage and good moisture holding capacity. The main physical constraint observed was the depth to coral on the shallower soils.

Soils were generally moderately acidic with a mean field pH of 6.1 in the topsoil and 5.9 in the subsoil. The soil pH increased dramatically in the parts of the soil profile near to the underlying coral. A test for the presence of allophane (Fieldes and Perrot 1966) which is important because it is a mineral that ties up phosphorus, was carried out across the sites and returned an average rating of 1 for both the topsoil and subsoils of the described sites (on a scale of 0-4 where 1 was rated as a very weak reaction taking 2 minutes to become apparent). Nutrient content at selected sites in three different regions of Santo is shown in Table 4. These soils had very low levels of available phosphorus according to general standards. However total phosphorus levels are likely to be high and the applicability of the available phosphorus tests to whitewood requirements is unknown.

Table 4 Nutrient contents at three sites selected across Santo.

	North		Central		South	
	Topsoil (0-10cm)	*Subsoil (30-50cm)*	*Topsoil (0-10cm)*	*Subsoil (30-50cm)*	*Topsoil (0-10cm)*	*Subsoil (30-50cm)*
Bray 1 P (mg/kg)	1.8	1.6	2.0	1.5	1.5	1.6
Colwell P (mg/kg)	21	67	40	55	56	170
Morgan P (mg/kg)	1.4	1	4.3	1	1	1
S (mg/kg)[1]	52.8	286.6	39.9	163.3	43.3	179.7
pHw	6.14	6.25	6.24	5.93	6.20	6.08
Ca (cmol$^+$/kg)[2]	17.14	4.91	18.29	8.20	11.15	2.54
Mg (cmol$^+$/kg)[2]	2.64	0.35	2.61	0.33	2.21	0.60
K (cmol$^+$/kg)[2]	1.16	0.25	1.52	0.18	0.38	0.23
Na (cmol$^+$/kg)[2]	0.11	0.15	0.10	0.20	0.09	0.06
Al (cmol$^+$/kg)[3]	0.01	0.02	0.02	0.01	0.01	0.01
H (cmol$^+$/kg)[3]	0.14	0.03	0.12	0.09	0.15	0.06
ECEC (cmol$^+$/kg)[4]	21.20	5.71	22.65	9.02	14.00	3.51
Ca/Mg	6	14	7	25	5	4
Zn (mg/kg)[5]	4.6	0.6	3.2	0.2	1.8	0.2
Mn (mg/kg)[5]	82	8	84	4	12	3
Fe (mg/kg)[5]	79	31	99	24	114	80
Cu (mg/kg)[5]	16.6	1.0	15.4	0.4	10.2	2.7
B (mg/kg)[6]	0.40	0.07	0.56	0.14	0.22	0.10
Total C (%)[7]	6.74	1.01	6.65	1.54	6.92	2.21
Total N (%)[7]	0.76	0.12	0.77	0.17	0.71	0.23
C/N Ratio	9	8	9	9	10	10

[1] KCl extract, [2]Ammonium acetate exchange, [2] KCl exchange, [4] Sum of exchangeable cations plus exchange acidity, [5] DPTA extract, [6] $CaCl_2$ extract, [7] LECO

In terms of suitability assessment, acceptable productivity was defined as mean annual wood volume increment of over 15m^3/ha/yr by age 15. Analysis of the data collected from the growth plots showed that all the plots could be fitted to the same growth model and that all sites had acceptable productivity, except at very low stockings (Section 6.3 and Grant *et al.* 2012)

Observations of existing plantations found high whitewood productivity on relatively deep, well structured and well drained soils. Land dominated by these soils on low slopes with low erodibility and with minimal limitations, and which is not forested and therefore is suitable for plantation development, totals around 78,000 ha on Santo (Figure 4). **Our conclusion was that on Santo there are approximately 78,000 ha of land highly suitable for whitewood plantations and 33,000 ha currently not intensively cultivated.** Thus there is vast potential for the development of whitewood plantations.

Figure 3. Woodlots and soil profiles from Santo

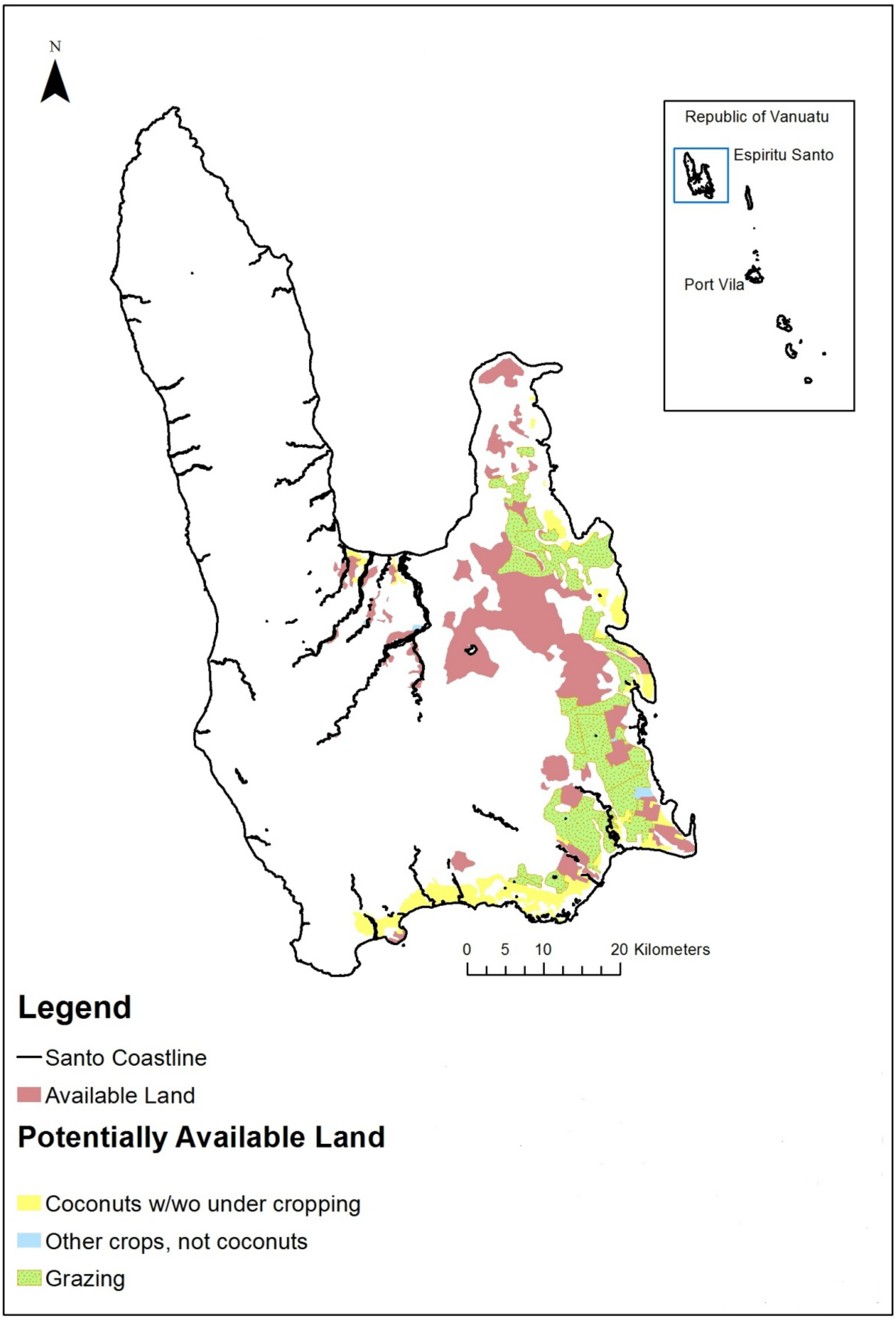


Figure 4. Availability of highly suitable land for whitewood plantation on Santo (conversion from other uses may be possible)

7.3 Growth and yield assessment and site indices for whitewood

The project established a network of 27 Permanent Sample Plots in woodlots throughout Santo. This will be a resource of great use to whitewood growers and processors as well as to the Department of Forests for many years to come.

A subset of the Permanent Sample Plots– 17 plots – had a mean age of 12 years, a mean stocking of 372 trees per ha, mean height of 19m and mean diameter of 29cm. Accumulated volume wood in these selected plots is shown in Figure 5. Grant et al. (2012b) with assistance in modelling from Professor Jerry Vanclay, estimated that a mean annual increment (MAI) of 20m3/ha/yr could be maintained over a 37 year rotation, with thinnings taking place at 20 and 26 years of age. This was thereby consistent with Thomson (2006), who estimated sustained yields in the range of 20-30 m3/ha/yr.

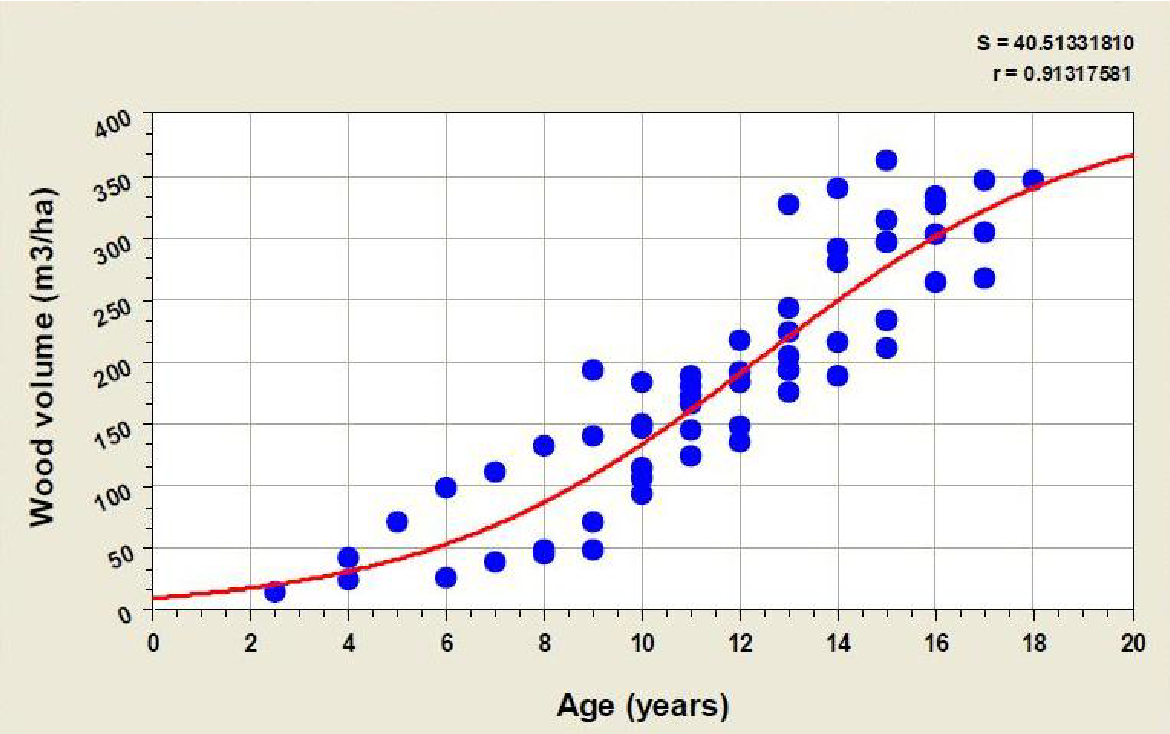


Figure 5. Accumulated wood volume as assessed in 17 woodlots.

Financial modelling indicated that either a scenario with two thinnings, or one in which only 400 trees were initially planted and only one thinning undertaken, would produce an internal rate of return greater than 5%. However, Glencross et al. (2012) recommend planting at least 600 per ha to be able to select final crop trees. Grant et al. (2012b) suggest a regime, based on an optimization exercise, in which the initial stocking is 635 stems per ha (6mx2.5m or nominal stocking), there are thinnings at ages 20 and 26 and a final harvest of 133 trees >55m cm diameter at age 36. More detail on the model is given in Section 6.8.

It was originally thought that there would a range of site qualities across the island of Santo. But after assessing soil and more than forty sites and after measuring whitewood trees in Permanent Sample Plots for several years, it became apparent that all sites examined were quite similar in terms of soil properties and expected yields of whitewood. Across the narrow range of sites on flat to rolling topography and accessible by road, the soils were all high-quality “Andisols” (volcanic soils with a black A “andic” horizon) and varying depths to limestone or coral. Unlike *Pinus radiata* site indices in New Zealand or Australia or Douglas-fir in Oregon, we did not find a range of sites in which growth would be significantly greater in some sites than others.

7.4 Whitewood establishment silviculture.

At a site called “Lorum” near Shark Bay on Santo, the project created a five ha establishment silviculture trial. The main questions concerned methods for merremia control, site preparation techniques using heavy equipment, fertilizer and initial spacing. Conclusions after three years of growth are that there were no significant differences in whitewood survival or growth by weed control treatment, whether by glyphosate, mechanical or manual control. Similarly, trees did not grow any better under a system of ripping than where rows were not ripped. Finally, none of the fertilizer treatments (described under Objective 2 of Methodology) of trees showed any significantly different responses to the control.

Smith et al. (2012) is a literature review on major topics in establishment silviculture, particularly as they pertain to tropical plantations, and concludes with examples from this project. Recommendations on establishment techniques are found in the Silviculture Manual (Appendix 2).

Importantly, we did observe that it is preferable to have heavy equipment drive over the top of vines and brush between tree rows, but not to disturb and scarify the site down to mineral soil. There are two major problems presented by having large areas of exposed soils: even though there is rainfall throughout the year, temperatures on exposed black volcanic soils can become lethal to young seedlings and secondly, sites disturbed to mineral soil tend to regenerate in pico – (*Solanum torvum*) – an aggressive spiny weed considered even less desirable than merremia.

In Vanuatu initial spacings of whitewood tend to be wide, with the highest densities at 4 x 3 metres, and 6 x 3m or 8 x 3m being two popular choices. In the Silviculture Manual (Appendix 2) we reiterate that the spacing chosen will depend on the objectives of the landholder. If it is wished to continue cultivation of crops for many years in the inter-row area then wider spacings may be chosen. If the objective is purely timber production, then closer spacing can lead to earlier crown closure and thus fewer weedings, and will reduce number and size of knots.

Agroforestry gardens, which are intensively managed on a small scale, provide an effective means for establishing whitewood. Heavy equipment can be used to push down heavy brush and merremia on a large scale. Intermediate plantings are more problematic in that the only option available to control the vines is to have periodic entries for manual control. This meant entries as often as twice a month in early stages. Our project found that total costs of establishment and manual weeding through three years were in excess of $3,000 per hectare. This means weeding up to thirty times, including twenty-four times during the first two years.

7.5 Whitewood plantation management: spacing and branch development

After establishment, control of merremia continues to be a serious issue. This project observed at several sites that the number of weed control entries could be reduced when whitewood was planted at closer spacings, specifically at 4 metres between rows and 3 metres between trees within rows. Another advantage of this closer spacing is that the number of branches and the sizes of branches and therefore of knots is reduced in comparison to wider plantings (Figure 5 and Figure 8) (Glencross et al. 2012). In other words, the process of self-pruning was enhanced by close spacing.

Disadvantages of close spacing are that it requires more trees to be planted initially, that the inter-row area is reduced and thereby not available for as long for agricultural crops, and, perhaps most importantly, that thinning of planted trees is required. The results of spacing and thinning trials are described in Glencross et al. (2012) and include the expected conclusion that diameter increment on residual crop trees is significantly higher than it is on trees in unthinned stands (Figures 6 and 7) and that diameter increment is greater in more widely spaced stands (Figure 8). The DoF Vanuatu and possibly another ACIAR project should be able to further measure the effects of thinning on growth and wood properties, which should become more pronounced over the next several years. These trials also serve as demonstration sites where growers can perhaps be persuaded of the importance of managing stand density.

Whitewood plantings were established at stockings of 400 – 833 trees per hectare and early growth, tree stem quality and branching were quantified up to age 4 years. Growth (Figure 8), as well as number of live branches (Figure 9a), and branch size (Figure 9b) were all negatively correlated with stocking. The stocking of acceptable quality trees had high spatial variation. To ensure that 300 stems per hectare of acceptable quality for pruning remain, more than 600 trees per hectare must be established at planting when “unimproved” seed is used, that is seed from general population of whitewood and not seed orchards. Improved seed would be expected to have higher quality stem form and therefore require fewer trees planted. Initial spacing in whitewood plantations can be used to manipulate branch size, crown rise and stem size, all of which are important for development of pruning and thinning regimes to produce high quality logs.

Practical advice on establishment and later management silviculture is contained in the 54-page illustrated Silviculture Manual, written by Kevin Glencross and Rexon Viranamangga (Appendix 2).

(a)

(b)

Figure 6. Closely spaced (4x3 metres) whitewood (a) at three years of age, where diameter growth will soon be declining. The advantage of closer spacing is that crown closure occurs earlier, necessitating fewer weedings and stimulating self-pruning. The disadvantages of closer spacing are that more trees need to be planted initially and will need to be thinned for high-quality sawlogs to develop. More widely spaced whitewood (b) at 6 x 3 metres. Fewer trees need to be planted but the plantation stays open for longer, meaning weeds need to be managed longer, and larger lower branches develop, which need to be pruned.

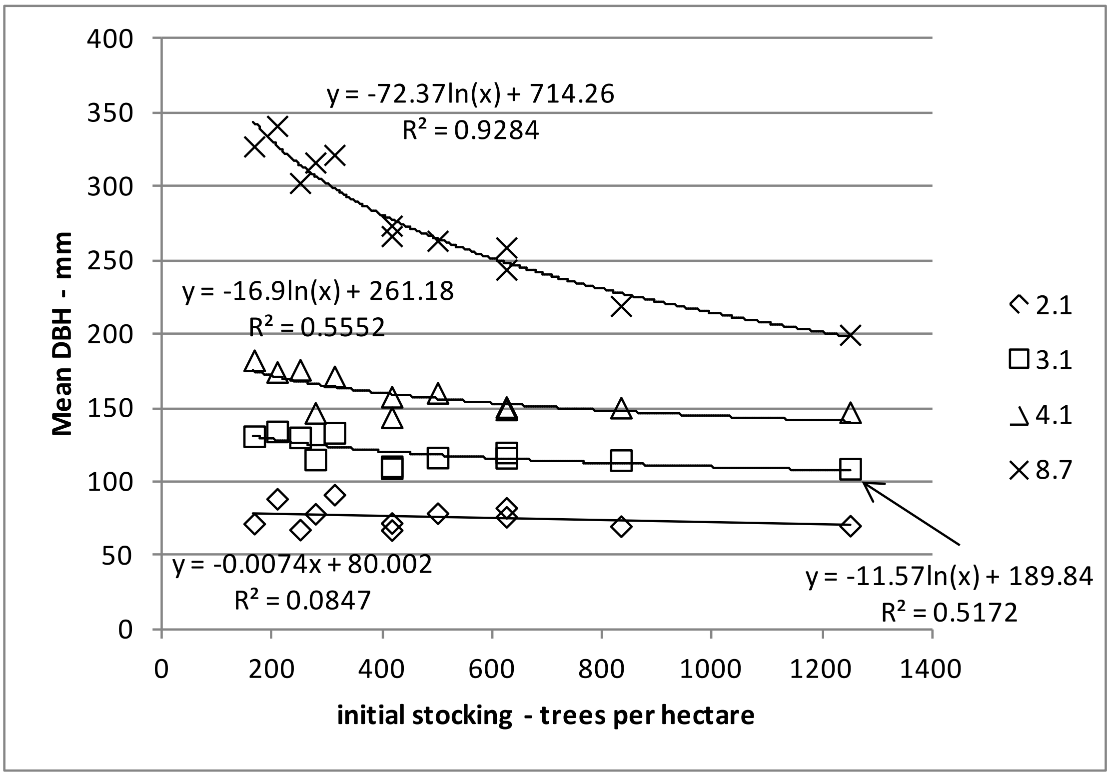


Figure 7. Diameter increment at Loro spacing trials at varying initial stockings. Each point represents the mean from two replicates for spacings listed in Table 1. Trees were measured at 2.1, 3.1, 4.1 and 8.7 years..

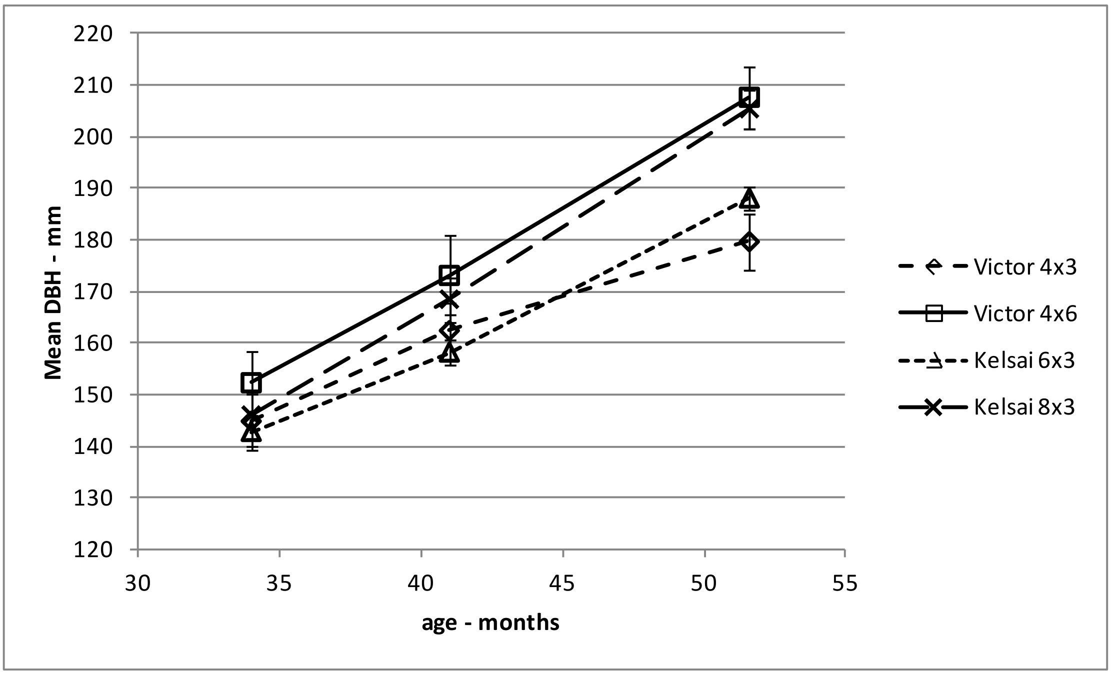
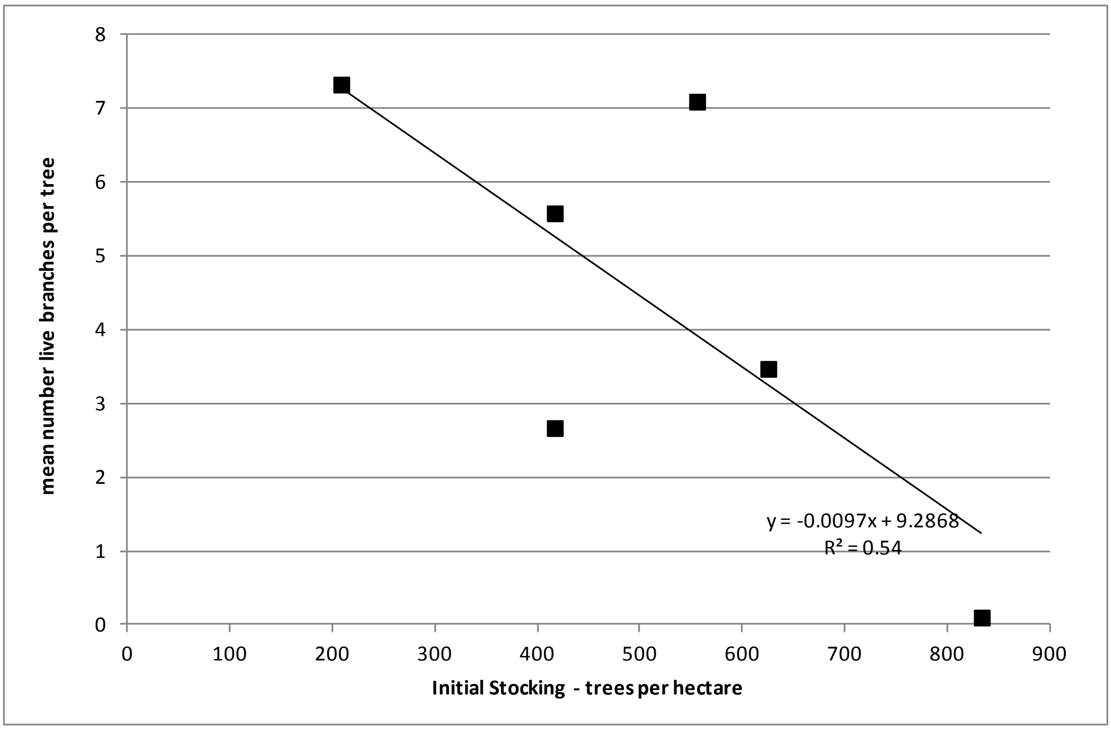
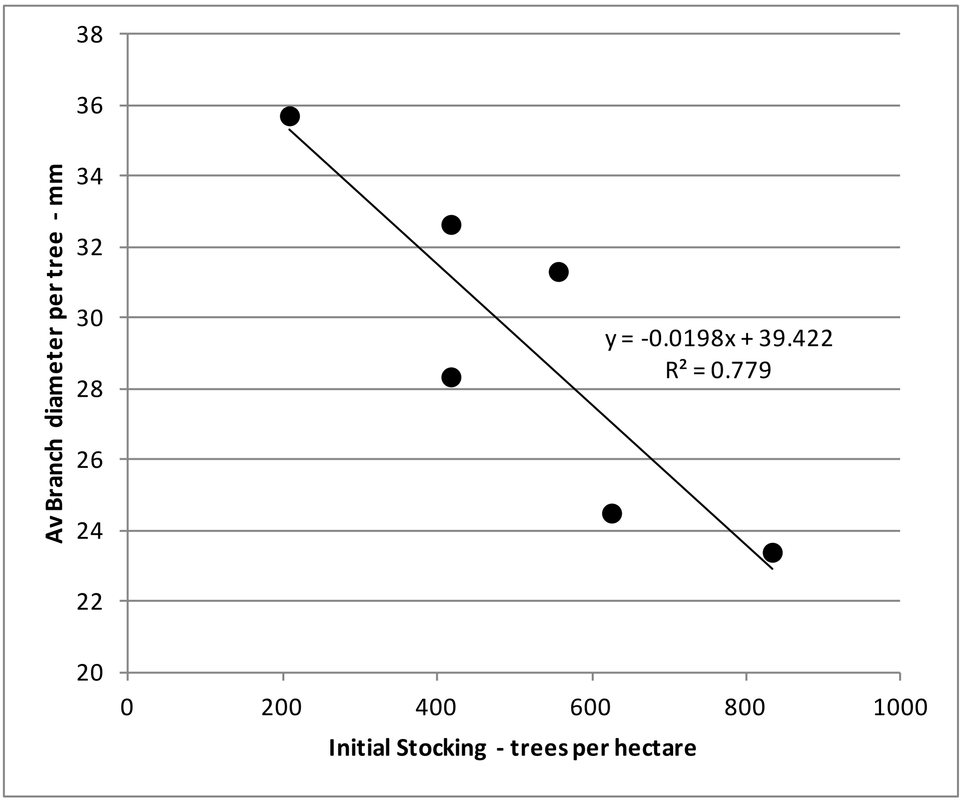


Figure 8. Diameter increment at different spacing trials.



(a)



(b)

Figure 9. The mean number of branches per tree (a) and average branch diameter per tree (b) both declined with increased stocking.

7.6 Agroforestry and mixed-species plantations

Originally it was proposed that the project combine *Eucalyptus pellita* and *Flueggea flexuosa* with whitewood in mixed-species trials however, *E. pellita* suffered considerably in cyclones recently in far north Queensland so it was decided to substitute the native *Terminalia catappa*, or natapoa, (Figure 10). After 36 months in replicated trials at

Malakai, the three species demonstrated variable survival rates and similar growth rates with whitewood being an average of 8.3m in height, namamau 4.8m and natapoa 9.6 m. Overall growth in the in mixtures is lower than in the monocultures with basal area of 2.7 m^2/ha in the mixtures, and a basal area of 4.3 m^2/ha in the whitewood monoculture (Table 5). As with monocultural plantings, monitoring and tending will be required.

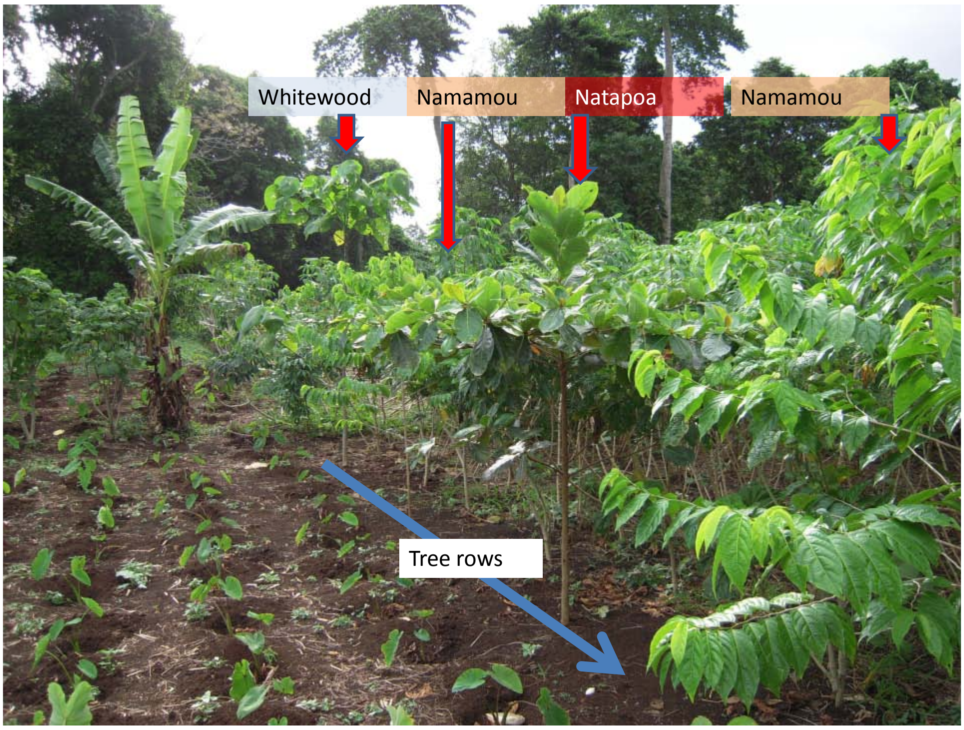


Figure 10. Three way mixture of whitewood, natapoa (*Terminalia catappa*), and namamau (*Flueggea flexuosa*) in an agroforestry garden.

Table 5- The growth and form of three species at the Malakai mixed species trial at 3 years old

	mixed species			Monoculture
	NTP*	NMM*	WWD*	WWD
spacing	8x8m	8x4m	8x8m	8x3m
Stocking (actual)	122	305	132	300
total basal area (m^2/ha)	0.09	0.89	1.70	4.35
Dbh mean (over bark mm)	31	61	128	138
Ht (m)	9.65**	4.8	8.3	9.7
mortality %	21	7	27	24
form	2.6	1.9	1.91	1.79
n	61	118	44	91
BA ha (m^2)		2.7		4.35
Total actual stocking		559		300

*NTP- Natapoa, NMM- Namamau, WWD- Whitewood

** Height of natapoa was based on trees that were free of borer damage

Although the three species may be compatible in terms of growth rates, natapoa suffers from attacks by an unidentified shoot borer (pers. comm. Simon Lawson, entomologist with Queensland government) (Figure 11). Further studies are proposed on development of the species in these trials, with assessment of patterns of aboveground biomass accumulation. Also a small ACIAR project is examining the growth and wood properties of *Terminalia catappa* in plantations on Santo and Efate.

Figure 11. Stem borer damage on a young natapoa (*Terminalia catappa*) seedling.

Vanuatu agroforestry gardens are well known for being highly diverse and productive. Because they are tended on a nearly daily basis, these gardens offer an ideal way, albeit on a small scale, to control the aggressive weed *Meremmia peltata*. In fact, some of the best examples of healthy fast-growing whitewood woodlots are in areas where the trees are combined with traditional multi-crop agroforestry. This is demonstrated at the replicated mixed-species plantations at Malakai (Sara) and at demonstrations sites at Jubilee Farms where trees are planted in one case with a diverse garden containing dozens of traditional crops and in another case with an older coconut plantation. The surveys conducted by Aru et al. (2012) confirm the wide variety of crops grown in combination with whitewood in agroforestry gardens (Figure 12).

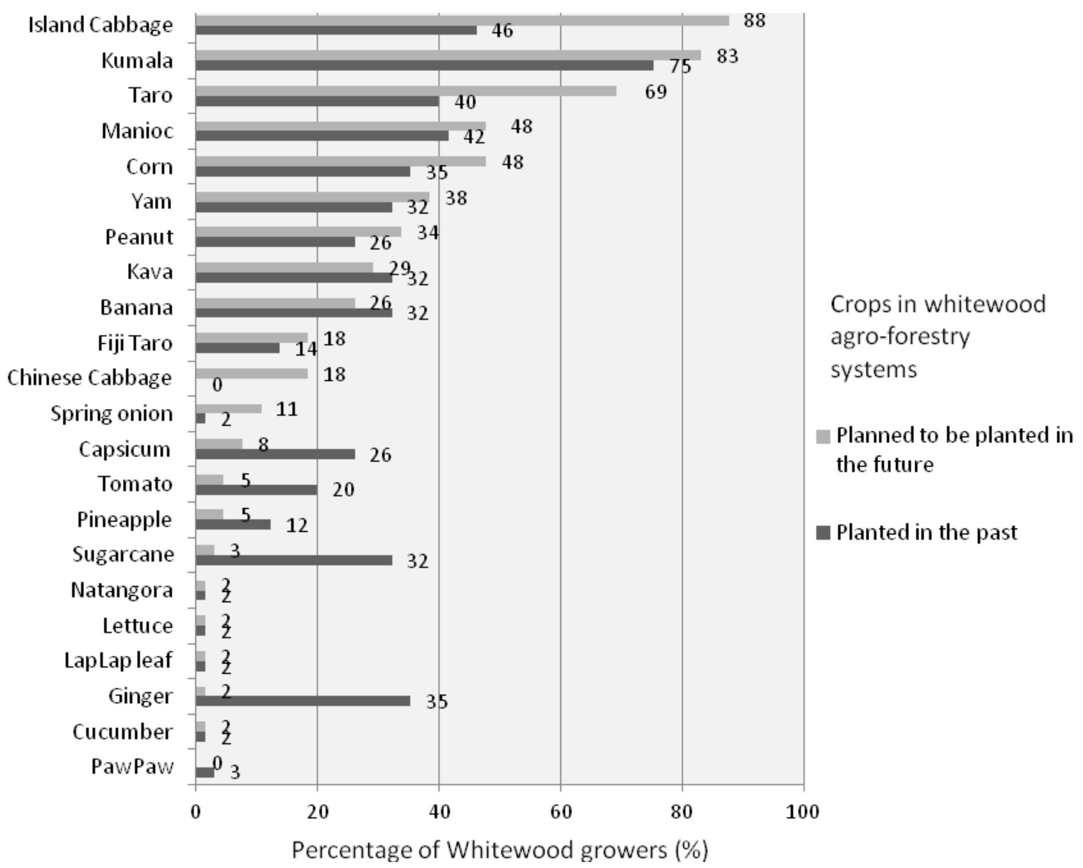


Figure 12. A wide variety of crops are combined with whitewood in agroforestry gardens in Vanuatu.

7.7 Wood properties of plantation-grown whitewood

Whitewood is a low-density, non-durable plain timber that is nevertheless considered highly desirable for certain uses, particularly interior ones. Project partner Melcoffee Sawmills has developed a working relationship with firms in Japan that buy finished mouldings. The subject of manufacturing mouldings from 15-year old whitewood logs was discussed by Mr Dick Tomker of DoF in a presentation at the final project conference. He and colleagues recorded a total of 2.5m3 in harvested logs, of which 30% was recovered. From this it was possible to make 140 pieces of flat moulding and 90 pieces of corner moulding, for a total value of 80,500 Vatu.

Because of the “global financial crisis” and possibly because Vanuatu was unable to supply the quantities of processed whitewood required by export markets the Japanese have found other sources of white or lightly coloured wood (McGregor and McGregor 2010), Vanuatu is no longer producing whitewood mouldings for export, although some of the raw boards sent to Noumea, New Caledonia are processed overseas for similar uses. The subject of the value-chain and possibilities for value-adding are still being investigated by Rexon Viranamangga, who is completing a John Allwright Masters scholarship in 2012. He has completed a second round of surveys of growers and processors on Santo and Efate Island as well as investigating the value chain of whitewood in New Caledonia.

A collaboration of this project with the whitewood/sandalwood germplasm project, ACIAR FST/2008/010, was a study of basic wood properties as they relate to provenance and family differences (Doran et al. 2012,). Measurements and samples were collected from the whitewood provenance-progeny trials at Shark Bay, which were planted in 1998 and 1999. It was found that mean unextracted wood basic density at breast height was 330kg per m^3, with a standard deviation of 21, a value similar to that in more mature trees. In a more detailed study of density in terms of radial variation using trees from the same trials, Settle et al. (2012) found a similar mean basic density at breast height (345kg/m^3) and significant and consistent increases in density from pith to bark, ranging from 308 up to 359kg/m^3. In general this project found that the properties of plantation-grown whitewood were comparable to those of native-forest whitewood, specifically in terms of basic density (Doran et al. 2012).

Measurements of the stiffness (modulus of elasticity or MOE) of whitewood indicate that a sectional dimension of 90 ×45 mm whitewood is approximately equivalent to 70 × 35 mm Australian softwood in a commonly used grade (MGP 10 - Plantation Timber Assoc. Australia, 1996). In respect of strength (modulus of rupture or MOR) however, a section of 150 × 60 mm whitewood equates to 70 × 35 mm of material graded as MGP 10. While these sectional comparisons indicate less efficient utilisation of whitewood, it is noteworthy that large sections offer opportunities to utilise the pith by sawing this defect into single boxed sections fully enclosing the pith, and the impact of larger knot defects can be more readily accommodated in large sections. Further research is required to establish mechanical properties in these large sizes to develop building design specifications using knotty structural whitewood (Viranamangga et al. 2012).

Trees with the best growth and best form were from Santo Island. The Kole (Santo) provenance showed the highest mean basic density, greatest mean diameter and greatest radial variation in density across the stem. Both the Doran and Settle studies confirmed that the characteristics of growth and density are heritable and that economic gains can be expected from recurrent selection and breeding programs.

The most important outcomes of the utilisation work are: that plantation-grown wood will produce less clear grade product than has been the case with native forest logs, that thinned stems need to return some money to growers while they wait on the final crop, and that lower grade wood from final crop stems should be utilised (Viranamangga et al. 2012). It was also found that there is sound basis for utilising lower grades for structural purposes despite the low density of the wood, in competition with imported radiata pine, if suitable specifications for structural sawn wood can be developed. Viranamangga et al. (2012) identified considerable potential for new products from whitewood, including shorter length clear wood that can be recovered from younger or lower quality trees and that can be used in furniture or jointed mouldings if sufficient resource is available to support investment in process (Table 6 and Figure 13)

Table 6. Proportion of over bark stem volume recovered in each appearance grade.

Appearance Grade	No of pieces	Proportion of volume (%)
1 = clear faces and edges	25	32%
2 = clear on one face and both edges	2	3%
3 = knotty excluding pith	37	34%
4 = pith included	32	31%
Total	96	100%

Finally Viranamangga et al. (2012) reported on preliminary tests with preservative treatments. Whitewood has low durability to biological degradation, but will readily take chemical preservative treatment (Groves and Wood 1998). This capacity represents a significant opportunity to add value to whitewood in Vanuatu, since outdoor and in ground products may be produced from any part of a log. Figure 13 illustrates that good penetration of preservative (Tanalith E) can be achieved into whitewood sapwood and heartwood. The end sections shown are from a piece 100mm × 100mm × 1m long, cross cut at its mid-point. The pith is evident as a small circular section near the top of the image and is surrounded by heartwood. Irregular penetration of preservative is indicated by wood of lighter green colour. The sample shown (Figure 14) was selected as the poorest penetration pattern achieved amongst six samples. Further research is required to test the efficacy of this preservative treatment in service, and possibly preservative-treated products could be developed for in-ground, weather-exposed end uses. These later points take advantage of the high permeability of the heartwood and its capacity to absorb chemicals through vacuum/pressure processes.

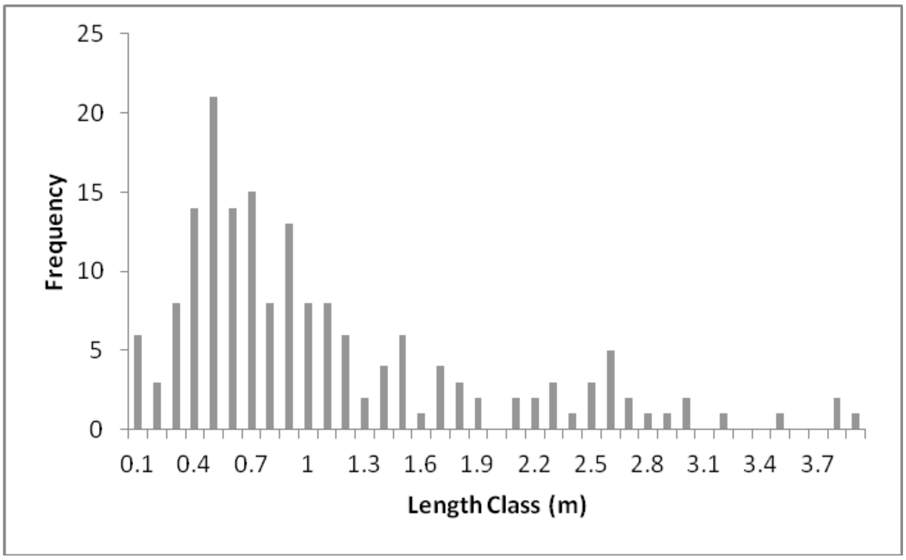


Figure 13. Frequency distribution (number of pieces) of clear wood recovered from knotty wood after cross cutting to remove defects.

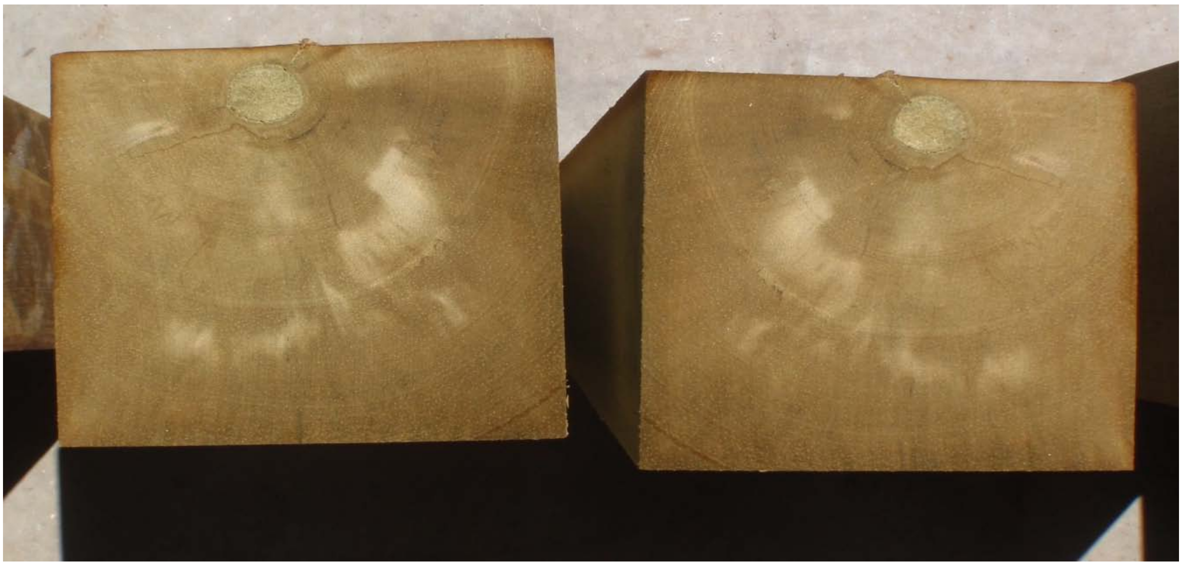


Figure 14. Penetration of copper based preservative (Tanalith E.) into the heartwood of whitewood.

7.8 Financial and economic aspects of whitewood from plantations in Vanuatu

The project commissioned a report on financial prospects of whitewood (McGregor and McGregor 2010). It concluded that the potential export markets for value added products from whitewood were not good, considering the decline in demand during the global financial crisis, the relatively high cost of labour in Vanuatu compared to countries with large capacity, like China, and the poor quality of sawmilling and processing available in Vanuatu. The findings of this report have been disputed by Vanuatu forest industry personnel, who feel the consultant did not properly consult them to gather factual information about previous experience at supplying value-added whitewood products to various export markets, particularly to Japan. The ACIAR Forestry Research Program Manager, Tony Bartlett, also disagrees with the consultant's approach and findings in that there is clear evidence that Japanese buyers are pleased with the product and willing to purchase it. It was argued that it is not really a valid comparison to say that it Vanuatu whitewood cannot compete with African hardwoods due to the comparatively high labour costs in Vanuatu. The two products and situations are not comparable.

Vanuatu does have some comparative advantages: its soil and rainfall patterns are quite conductive to high levels of production, and establishment and maintenance costs can be quite low, particularly when done by family or community groups who not expecting to be paid. Further, the fact that Melcoffee Sawmills was able to sell whitewood mouldings to a Japanese customer in the 1990s and early 2000s indicates that this option may yet be viable. Finally, there are options that have yet to be developed, and perhaps will be in a subsequent project. These include exploring the use of inexpensive locally-applied wood treatment facilities and developing uses for knotty plantation-grown wood and short pieces of clear wood.

The topic of opportunities for value-adding whitewood is discussed in detail in the paper by Viranamangga, Palmer and Glencross (2012). These authors estimated that plantation-grown whitewood will have about 30% more knotty wood than previously found in logs from native forest and not that the presence of knots does lower the value of wood (Table 6 and Figure 13). This will impact on the economics of growing and processing whitewood, and on potential uses of the timber. Opportunities to add value to knotty wood are to produce large section structural lumber, to recover short lengths of clear wood for furniture, and to treat heartwood with preservative chemicals to enable structural use in exposed and in-ground applications. This subject continues to be analysed in Mr Viranamangga’s Masters work at SCU. Mr Viranamangga’s thesis, to be submitted in early 2013, will contain a detailed analysis of the whitewood value-chain, and further insights into value-adding possibilities, based on a second set of surveys he undertook in July 2012.

Financial model

Given a utilization limit of 15 cm small end diameter, an establishment cost of $165/ha plus $4.40/tree, plus a pruning cost of $0.90/tree, an annual maintenance cost of $5/year (Glencross, pers comm.), and a discount rate of 5%, the model developed by project staff predicts an **optimal** silvicultural regime with an initial stocking of 635 stems/ha (at least 600 stems/ha are recommended, to have adequate selection of crop trees) two thinnings at age 20 and 26 years, and a clearfall at age 36 yielding 134 stems at 55 cm dbh. However, the optimum is a **broad plateau**, with a wide range of conditions (e.g., initial stocking ±30%) that offer returns within 5% of the optimum.

The model is available from the authors of Grant et al. (2012b) as an Excel spreadsheet (Figure 15). In this figure, the left pane reports the simulated data, and the right pane includes the model parameters (top right, shaded grey, password protected), utilisation and financial data (such as small end diameter and establishment costs), silvicultural data (such as initial number of plants and age of thinning), and a summary of simulation results (bottom right, shaded grey). The parameters in the ‘silviculture’ pane may be set by the user.

Age	Height	DBH	N/ha	BA	Vol/ tree	Standing Volume	Standing Value $	MAI vol	Cost	NPV $	Model parameters	Estimates
1	4.0	3.9	635	1	0	0	0	0.0	2,959	-2,959	h=root(A-.5)	5.65
2	6.9	8.1	635	3	0	0	0	0.0	5	-2,964	d=h/lnN	9.3
3	8.9	11.0	635	6	0	0	0	0.0	258	-3,222	Gmax	50
4	10.6	13.4	634	9	0.00	0	0	0.0	4	-3,226	Min SED	15
5	12.0	15.4	633	12	0.01	7	13	1.3	4	-3,216	Discount rate	5%
6	13.3	17.2	631	15	0.05	33	318	5.5	319	-3,231	Initial costs $/ha	165
7	14.4	18.9	627	18	0.10	61	892	8.7	4	-2,661	Establish cost $/tree	4.4
8	15.5	20.5	623	20	0.14	90	1,625	11.2	3	-1,931	Annual costs $/ha	5
9	16.5	21.9	616	23	0.20	120	2,450	13.4	3	-1,109	Prune1 cost $/tree	0.4
10	17.4	23.3	608	26	0.25	151	3,320	15.1	3	-242	Prune2 cost $/tree	0.5
11	18.3	24.7	598	29	0.31	183	4,199	16.6	3	634	Thinning cost $/ha	1600
12	19.2	26.0	586	31	0.37	215	5,061	17.9	3	1,494	Initial number	635
13	20.0	27.3	573	33	0.43	247	5,886	19.0	3	2,316	T1 age	20
14	20.8	28.5	558	36	0.50	278	6,658	19.9	3	3,085	T1 residual	0.66
15	21.5	29.8	541	38	0.57	309	7,366	20.6	2	3,790	T2 age	26
16	22.2	31.0	524	39	0.65	339	8,003	21.2	2	4,425	T2 residual	0.50
17	23.0	32.2	506	41	0.73	368	8,564	21.6	2	4,984	Clearfall age	36
18	23.6	33.4	488	43	0.81	395	9,050	22.0	2	5,468	Max Standing Val	13,132
19	24.3	34.6	469	44	0.90	422	9,461	22.2	2	5,877	Max MAI	22.7
20	24.9	35.8	310	31	0.99	308	10,204	15.4	605	6,016	Max NPV	8,472

Figure 15. Screen save of whitewood model, showing model parameters and negative and positive Net Present Values (NPV in $). Model parameters are listed in the right-hand column.

Using the spreadsheet model it is possible to project and graph changes in mean stem diameter, total basal area, number of trees per ha, and total volume (Figure 16). One unknown about whitewood is whether its diameter growth will continue well beyond twenty years of age. “Long-lived pioneer” species such as whitewood often exhibit strong diameter growth until sudden death (Metcalf et al. 2009) and can attain quite large diameters (Thomson 2006) so that the diameters projected in this figure seem plausible. Market conditions vary over time, with the advantage that trees can be “held over” if prices are poor or harvest is not able to be achieved. At present Melcoffe Sawmills is beginning to harvest trees from its 270 ha of 17-year old trees (Figure 17).

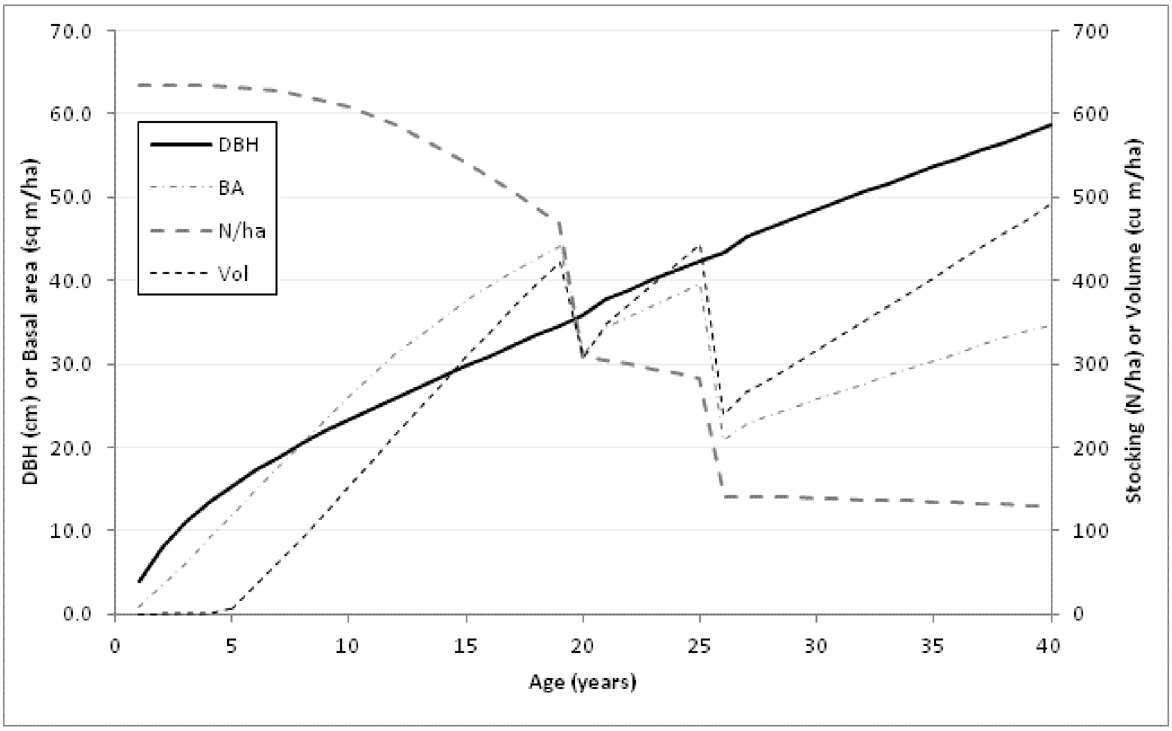


Figure 16. Simulated outputs for optimal silviculture.

Figure 17. Logs harvested from 17-year old stand of whitewood (background) at Loro plantation, Santo

8 Impacts

8.1 Scientific impacts – now and in 5 years

The work of this project fits into the overall process of "domestication of native rainforest tree species". The project group is publishing a special issue of International Forestry Review 14 (4), 2012, on the theme of rainforest tree domestication. We review efforts on this topic around the world in tropical countries and use the whitewood project as a case study in the domestication process.

The nine articles for this special issue (titles and authors under "publications" in this document) are being written by the various project scientists, Nichols, Glencross, Grant, Smith, and Palmer, in collaboration with Vanuatu project staff, including Rexon Viranamangga, Mesek Sethy and Ioan Viji, and Rodney Aru. Two papers were written in collaboration with ACIAR project FST/2008/010 scientists John Doran and Tony Page.

Since the 1980s whitewood has been clearly identified as a valuable species for use in plantations. The current project comes after the ten-year AusAID South Pacific Regional Initiative on Forest Genetics (SPRIG) program, which among other things set up the seed orchard used now to produce seed and for assessing the effects of genotypes on growth and wood properties.

Establishment silviculture experiments supported the general recommendations given for plantations in tropical areas (Smith et al. 2012) although the soils at this project's trial sites supplied adequate nutrients to trees without the addition of fertiliser, whereas often fertilizer provides a benefit and is recommended at establishment.

The four-year results from trials instigated by this project provide a scientific basis for whitewood silviculture, particularly in establishment, pruning, thinning and wood quality. Also the project's 27 Permanent Sample Plots indicate that the species can produce comparatively high growth rates, of approximately 20 cubic metres per ha per year over 17 years. At this rate of production a landholder could sell 340m3 at 17 years of age for an undiscounted amount of $17,000, at $50 per cubic metre. Alternatively, he could wait for his trees to mature, and-or sell boards rather than standing trees or further engage in processing and thereby potentially earn more.

The long-term scientific impact of this project will be to add various specific details in relation to whitewood's needs, in large-scale and small plantings and this will add to the world literature on the domestication of rainforest species. A great deal was known of rainforest species by indigenous people, though much of this knowledge was lost throughout the colonial periods. Then foresters from the occupying countries developed silvicultural knowledge, which has been partially retained but also partially lost as countries became independent and forest services experienced considerable flux, poor funding and ever changing priorities. We contribute here in the current mode, which is hypothesis-based, and somewhat more quantitative and experiment-based than the older methods of forestry development.

This whitewood silviculture project will be maintaining through the year 2013 a series of 15 ha of whitewood trials, demonstration plots, and 27 PSPs. Since forestry is a long-term operation, these trials can continue to prove useful if they are maintained and measured well into the future: this is a legacy of the project which we hope will not be lost.

8.2 Capacity impacts – now and in 5 years

Training for government staff, extension to landholders

Capacity building was in two overlapping categories: professional and technical development. DoF staff, students at VAC, landholders, whitewood growers and whitewood processors undertook training in technical activities necessary for plantation research and management.

We aimed to use the extensive establishment of experiments as training tool with professional and technical staff involved in the design and implementation of trials on the ground. DoF staff involved includes Mesek Sethy, Ioan Viji, Tate Hanington, Leimon Kalomor, Rexon Viranamangga and several trainees on Santo.

The trials and PSPs exist not only on the ground but as data files which should be updated periodically and form the basis for training staff in analysis and communication of results of experiments.

At the request of DoF Director Livo Mele, two workshops on basic statistics and experimental design and analysis were organized. The first was delivered in mid-2011 by John Grant of SCU, soil science lecturer. It was held on Santo with 10 persons in attendance, mostly staff from DoF but also including Rodney Aru, VAC forestry program. This workshop was reported to have been highly successful with classroom computer session, group field work to collect data and computers analysis of data. Thus the theoretical and "hands-on" were integrated over the two-day workshop. Nichols delivered a similar workshop in Port Vila later in 2011.

Also in 2011 a SCU forestry graduate, former employee of Forest Enterprises Australia, and specialist in GIS Therese Moffat, travelled to Santo and delivered a training course on the use of GIS in forestry. Students, including those from both DoF and VAC, were given an orientation into the use of GPS tools and made aware of the net-based resources available for mapping and incorporating GIS into forestry work. Ms Moffat combined field and computer laboratory exercises to provide a useful introduction to GIS.

Capacity building – one year of AYAD volunteers

One area of university forestry programs that is most appealing to Australian students is the opportunity to travel and work internationally. This project was fortunate to have two SCU forestry graduates take Australian Youth Ambassadors in Development positions. One was Kate Convery, who spent six months on Santo with the project in 2008, and the other Bronnie Grieve, who spent a further six months in 2009-10.

Thus the project in effect had Australian staff on the ground in Vanuatu for nearly one year. This greatly facilitated the difficult administrative tasks of funds transfer, computer setup and maintenance, etc. but also meant that these two exceptional forestry graduates were able, on a daily basis, to share their knowledge of practical forestry and forest research methods with project staff. This primarily was DoF Vanuatu staff but also students in forestry certificate program at VAC, landholders, sawmillers and others connected with whitewood growing or processing.

A particular contribution of both AYAD volunteers was developing a systematic method for recording data and storing it in Excel spreadsheets. Bronnie Grieve took the process started by Kate Convery a step further, and created an Access database for all project trials. Amongst DoF staff Leimon Kalomor was especially involved in the process and developed considerable capacity in preparing data sets and storing them.

Computers and software and files are all very difficult to maintain in Luganville, with inconsistent power, salt spray, high humidity, poor virus protection and lack of access to replacement parts and software. All Australian staff attempted to communicate the importance of computer security but these issues are ongoing.

We emphasised repeatedly the importance of backup of files. In fact we were not able to find any central data files anywhere in DoF, either on Santo or in the main office in Port Vila. Eventually we were able to gain access to some files from the SPRIG project in CSIRO in Canberra, but never found copies of spreadsheets on other trials such as Industrial Forestry Plantation and ones done by various international projects – only fragments of hard copies of some of them.

If the forest research sector is to become strong in Vanuatu and DoF to be a part of it, then this problem needs to be resolved. A good model for DoF to follow was implemented by Dr Geoff Smith, maintaining multiple copies of data sets stored in different locations. The DoF office has burned down twice on Espiritu Santo making data security a high priority. DoF now has an opportunity to build a strong, secure set of files on valuable forest research in the country.

Tertiary training

This whitewood silviculture project has been incorporated into the forest science and management curriculum at Southern Cross University. Nichols uses examples from the project in classes in Agroforestry and Farm Forestry, Forest Health, and in general lectures. Grant shares knowledge of tropical soils, particularly the andisols that dominate on Santo Island, with students in units Soil Processes and Land Degradation and Rehabilitation. Glencross incorporates example of whitewood trials into his work with the Water and Carbon Group. Palmer discusses challenges of small tree processing in Wood Science and Product Development and Marketing.

Mr Simon Perrow, an SCU forest science and management undergraduate, did an integrated project on taungya agroforestry – literature review with case study of whitewood in Vanuatu. He presented at conference on Santo in November 2011.

Rexon Viranamangga, senior officer of Department of Forests Vanuatu, received an Allwright scholarship to SCU. To study the whitewood value-chain. Mr Viranamangga conducted interviews of landholders, growers and mill owners between November 2011and July 2012, in Santo, Efate and New Caledonia. He is currently writing his Masters thesis, due for completion early 2013.

Extensive technical training

This project may or may not have succeeded had the responsibility for on-the-ground implementation rested solely with professional Australian and -Vanuatu staff. One of the ironies of university education is that sometimes having an undergraduate degree, or postgraduate qualifications, exempts one from tedious “hands dirty” work. The whitewood silviculture project relied on the enthusiasm of a technical officer – Mr Mesek Sethy – who ensured that the numerous and large trials were established and maintained, often in very trying circumstances. Further, several technical officer colleagues, with potential eventually to do 4-year forestry degrees, assisted Mr Sethy. Most notable of these was Mr Sammy Kaku, who worked for the project over the beginning two years.

Thus we believe it appropriate that Mr Sethy visited SCU twice during the project lifetime and Mr Kaku once, to receive training in field silviculture, wood sampling from standing trees, destructive sampling and protocols and the use of equipment in the wood science laboratory at SCU. They were then able to explain these technologies to their colleagues in Vanuatu, forestry officers, technicians, students at VAC, sawmillers, and landholders interested in plantation management and wood processing.

Capacity impacts – training materials

In the appendixes are a collection of extension and training materials developed by the project (Appendixes 2-5). Of primary importance is the Silviculture Manual on whitewood (Appendix 2), prepared by Dr Kevin Glencross, who coordinated most of the trials and workshops. This has been developed in an English version that will be most useful to professional staff of DoF and to forestry students, both ni- Vanuatu and international. A shorter version is being translated into Bislama and will be distributed around Santo and the other islands where there is potential for whitewood plantations.

Also in the appendixes are a four-page brochure on whitewood in Bislama and examples of posters on growing whitewood (Appendix 3) and on the details of the Lorum silviculture trials (Appendix 4). The latter is displayed at key Department of Forests offices and also on a sheltered poster board at the entrance to the Lorum trial site.

8.3 Community impacts – now and in 5 years

In five years we might expect that there will be a vigorous whitewood plantation sector on Santo. The germplasm - improved seed from 15-year old whitewood seed orchards - is available to support this development and more seed orchards are now being established. Further, the expertise found in private companies as well as government institutions such as DoF and VAC, is increasing every year, through the impacts of projects like this one. This sector of technical and professional expertise is well set to guide a significant plantation based forest industry.

8.4 Economic impacts

The silvicultural guidelines developed by this project, as outlined in the Silviculture Manual, if applied, may make whitewood plantations a profitable activity. The modelling work summarized in the paper by Grant et al. (2012b) indicates that a broad range of management regimes, with varying spacing and rotation lengths, may achieve an internal rate of return of 5% of more. These assume a price per cubic metre of standing trees of $50 for trees with 30cm dbh or greater. This article models a variety of scenarios with rotations up to 37 years of age, and yields from 16 to 22 m3 per ha per yr. The model suggests that an optimal silviculture for whitewood may be to plant 635 stems/ha, two thinning at age 20 and 26 years, and a clearfall at age 36 yielding 133 stems at 55 cm dbh. Alternatively, if the market for thinnings is weak and improved stock is available, it may be preferable to plant 400 stems/ha, have a single thinning at age 24, and to clearfell at age 34 to yield 145 stems at 54 cm dbh.(Grant et al. 2012b).

Even with a conservative estimate of 15 m3 growth per year over a 20 year rotation and a low price of $50 per m3, 300 m3 of whitewood trees on one hectare would yield $15,000 (not discounted), a considerable sum in a country where per capita GDP was $1,138 USD in 2002 (Jayaraman and Ward 2006). Larger trees, particularly if well managed for clearwood production, could bring up to $100 per cubic metre. Likewise, processing into boards for resawing, drying and chemically treating timber, and even making final products all offer opportunities for larger earnings. Also, these activities all represent spending that will replace imported pine, having a significant multiplier effect in employment and other local expenditure.

Through this project and its many field days, workshops, extension materials and ongoing contact with landholders and whitewood growers, it has been shown that whitewood trees can be better managed to produce larger, higher quality stems through pruning and thinning. It has also shown local growers and processors that there are various options for a whitewood tree: letting it grow on to become larger, selling the standing tree to the highest bidder, processing trees to raw board form on-farm, and-or working collaboratively with processors to produce higher value material, especially mouldings.

8.5 Social impacts

The results of the surveys (Results 6.1 and Aru et al. 2012) indicated a surprising lack of interest in planting whitewood. In spite of 25 years or so of promotion and extension work about the potential of this species for cash-generation for landholders (and many consultancies on the topic), the survey team encountered a general lack of belief that whitewood could be profitably grown.

The establishment of 15 ha of trials and encouragement of maintenance of previously planted woodlots have given whitewood plantations a higher visibility in many communities on Santo. Since these plantings required two weedings per month in the first two years and monthly weeding subsequently, a considerable amount of work was provided for many community groups through the project.

Workshops on whitewood silviculture on farms and on processing of logs brought together people from many levels of society on Santo, including agriculture students, forestry trainees, and landholders with DoF staff and wood processors.

8.6 Environmental impacts

The project established some 15 ha of new trials throughout Santo Island, and additionally encouraged the establishment of new plantations. These alone constitute reforested areas and provide an example of a viable land use conceivably applicable to large areas of land which is already deforested and dominated by weeds like merremia, but not currently in any economic land use. The project encouraged the use of manual non-chemical methods for plantation management, demonstrating at Lorum trials that glyphosate use was not significantly more effective than manual control of weeds.

8.7 Communication and dissemination activities

Workshops

Dr Kevin Glencross led five workshops, in addition to the final conference with its day of presentations and field trip.

These workshops brought together DoF professional and technical staff, employees of Melcoffee Sawmills, landholders and wood processors and staff and students of the forestry certificate program at Vanuatu Agriculture College in Santo.

Workshops and field days were held at the major trial sites of the project:

Victor Andre’s plantation, the first established by the project, and a good example of whitewood agroforestry with one main cash crop, peanuts. It was also used for thinning experiments and to demonstrate issues with spacing, branching and needs for pruning and thinning.

Malakai’s farm near Shark Bay. Mr Malakai is very active landholder and “early adopter” as classified in the extension literature, hardworking and willing to experiment with new crops and techniques. His farm is located in heavier brush conditions dominated by hibiscus. It is also the site of major replicated experiments combining whitewood with natapoa and namamau.

Lorum and Kelsai trials. Mr Kelsai’s is primarily a whitewood thinning trial adjacent to the large Lorum whitewood silvicultural trial, on the main highway and convenient for field days.

Jubilee Farms. Here there are two demonstration plantings, one whitewood combined with traditional complex agroforestry gardens and another underplanting of whitewood, namamau and natapoa in older coconut plantation. Jubilee Farms is very accessible for field trips from VAC or Luganville.

One of the most important workshops was held at the Industrial Forestry Plantation (IFP), one of the first sites where whitewood plantations were established and therefore with the oldest and largest trees. At this site Dr Glencross and team were able to demonstrate the initial stages of tree assessment, felling techniques and conversion to boards.

There were two workshops held at Vanuatu Agriculture College. Although the VAC forestry program did not exist at the beginning of this project, it was integrated into whitewood project activities after its inception during the project. Thus forestry students, led by Rodney Aru, formerly of DoF Vanuatu and Melcoffee Sawmills and co-leader of this project in its first year, were able to participate in hands-on training exercises in whitewood plantations and in the processing of whitewood logs.

There were also two workshops held at Melcoffee Sawmills, a partner in this project and a pioneer in the domestication of whitewood. Here Dr Glencross and Dr Graeme Palmer, lecturer in Wood Science, Product Development and Marketing at SCU, were able to demonstrate the equipment and techniques used to produce a range of materials from plantation-grown whitewood logs, from raw low-grade utility boards to the most refined mouldings, suitable for export to highly demanding markets. This gave landholders, forestry students, and forest management staff insights into what happens to the tree – and what qualities the tree needs to have – for successfull conversion into valuable products.

9 Conclusions and recommendations

9.1 Conclusions

Whitewood has been conclusively proven to be a viable plantation species, growing at approximately 20 cubic metres per ha per year for at least 17 years. It is able to maintain such a rate because of its own nature and the high rainfall and fertile soils of Vanuatu. There are approximately 78,000 ha of land suitable for whitewood plantations, 33,000 ha of them not currently being used, on Santo Island. If we conservatively estimate a production of 15 m^3 per ha per year, a rotation length of 20 years, and a recovery rate of 33%, then a factory producing 10,000 m^3 of finished product per year could be supported by an estate in which 100 hectares per year are harvested, or a total area of 2000 ha.

Although whitewood plantations can indeed be established, and labour costs are lower than in developed countries there is an ongoing problem on the weed *Merremia peltata*, which costs more than $3000 per ha to control in the early years of a plantation, using bush knifes. Close spacings limit the length of time that weed control is necessary but commit that given piece of land to tree plantation. This project used only one herbicide, glyphosate (Roundup) and did not find that it was more effective or less expensive than manual clearing. Close spacings also restrict branch size and make pruning easier to perform, an important step if high-quality clear (knot-free) sawlogs are to be produced.

In terms of initial spacing of plantations, it was found that with fewer than 400 trees per ha (approximately 8 x 3m), knots larger than 25 mm tended to develop (Figure 8). At 6m x 3m there was improved crown rise and better self-pruning. Finally it was concluded that 4m x 3m (833 trees per ha) should be the recommended spacing, since it provides enough trees to choose a final 200-300 crop trees and creates a stand in which self-pruning eliminates undesirable lower branches.

In social-economic surveys and numerous workshops and field days we found little certainty that investing in whitewood plantations, other than at a small woodlot scale, was a wise decision. This is in spite of many years of extension work by the DoF and international projects in promoting whitewood. Landholders generally believed that they had few options for selling standing trees, that the prices would be quite low if they did sell, and that as yet there were few opportunities for on-farm value-adding.

Plantation-grown whitewood will have about 30% more knotty wood than previously experienced in logs from native forest. This will impact on the economics of growing and processing whitewood, and on potential uses of the timber. Opportunities to add value to knotty wood are to produce large section structural lumber, to recover short lengths of clear wood for furniture, and to treat heartwood, which was found to be easily penetrated, with preservative chemicals to enable structural use in exposed and in-ground applications.

Thus we concluded that there need to be continuing efforts to open new ways to process and sell whitewood, in varying degrees of sophistication, from the standing tree to processed mouldings that can be sold in the most demanding markets, as in Japan and New Caledonia. This new work should focus on appropriate techniques for treatment, protecting whitewood from the blue stain and borers which almost immediately attack fallen trees, and on devising uses, for both internal and export purposes, for short sections of clear wood as well as for the more commonly available knotty wood.

9.2 Recommendations

For forestry research to develop successfully and lend strong support to a vital plantation sector in Vanuatu, it is important to have long-term secure storage of data, research trial designs and results of experiments. This does not currently exist, with each project, local or international, having a finite life span and there being no structure for maintenance of data, either in hardcopy or computer files. Further, the physical and cyber conditions in the country are such that actually creating and maintaining such a data base is quite challenging. Thus we can recommend that a small project be launched to develop a plan for unifying the data sets and results of all forestry work done so far, as inter-institutional collaborative work.

Whitewood plantations can be divided into two general categories: industrial plantations and smaller landholder owned and managed woodlots. This distinction has been made since at least the 1980s when the idea of “Industrial Forestry Plantations” was promoted for an area of 500 ha near Shark Bay.

Although many consultant reports have been written over the last twenty-five years, all of them illuminating the great potential of large-scale whitewood plantations (including Nichols 2003) only one “large-scale” plantation has actually been established and taken through to harvest. This is the 270 ha Loro plantation of Melcoffee Sawmills from the mid-1990s. It has certainly demonstrated the viability of such plantings, as now this small sawmilling business is able to maintain itself from harvesting these well-developed trees of 17 years. In the case of small woodlots there is a lack of expansion, with Aru et al. (2012) finding only 64 ha of planted whitewood amongst the 139 landowners interviewed. Some landholders expressed interest in creating more small plantations of mahogany and other species as well as whitewood. Generally we recommend the development of various options along the value-chain, including investigation of chemical treatment options, uses for small material and uses for knotty boards, and uses for roundwood (poles), for there to be better reasons to plant whitewood. Some growers may choose to stop at the stage of selling a standing tree whilst others may wish to go on, to fell trees, and saw them into boards or other products. If the only option remains to sell standing trees at an unknown but likely low price, then we can expect little expansion of the small woodlot sector.

In summary:

Whitewood project trials should be maintained on the ground and re-measured annually, becoming permanent part of estate on Santo and in databases.

Although heavy equipment can be used to run over Merremia (not disturbing the soil) for large-scale plantations, and agroforestry gardens and crops like kava and peanuts can be used for small-scale whitewood plantations, there is a need for ongoing research into effective methods of weed control. The staff of this project did not wish to promote the use of herbicides in a developing country, but the cost of manual weed control is nevertheless very high – as much as $3000 per hectare for establishment.

The findings of this project, and techniques for silviculture, should continue to be shared with communities of landholders, and with potential large-scale investors.

Continuing work should be done on mixtures that include native species other than whitewood, leading to lower risk of investment and higher biodiversity in plantations.

Most importantly from meetings with stakeholders, research needs to continue on the details of the value-chain and opportunities for value-adding, particularly for small landholders and communities. This should include work on low-cost portable methods for treating whitewood and for developing new products from small knotty, plantation-grown trees.

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(Chronological order)

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Conference presentations:

Nichols, J.D., Glencross, K., Grant, J., Convery, K., Vira, R. Viji, I., Croucher, N., Aru, R 2010. Whitewood (*Endospermum medullosum*) in Vanuatu: development of the silviculture of a native rainforest species. Presented at *National Conference of Australian Forest Growers*, 10-13 October 2010, Mount Gambier, South Australia.

Conference held 30 November 2011, Luganville, Santo, Vanuatu (field day 29 November)

ACIAR Whitewood Silviculture Project

Conference Program

30 November 2011

Luganville, Santo, VANUATU

ACIAR Forestry	**Tony Bartlett**
Plantation forests in the tropics	**Jerry Vanclay**
Introduction to Conference of ACIAR Whitewood silviculture project	**Doland Nichols**
History of Whitewood development in Vanuatu	**Tate Hanington**
Site characteristics, soils on Espiritu Santo, estimate of land available for Whitewood planting	**John Grant**
Yield estimates from Permanent Sample Plots	**John Grant**
Landholder survey results	**Rodney Aru**
Site-preparation recommendations, fertilizer experiments, weeding recommendations, Lorum results.	**RGB Smith**
Spacing: to prune or to thin?	**Kevin Glencross**
Review options for other species	**Doland Nichols**
Mixtures: results from Malakai trials	**Leimon Kalomor**
The market for Whitewood and financial aspects of plantation establishment	**Rexon Viranamangga**
Agroforestry potential	**Simon Perrow**
Melcoffee Sawmills and Whitewood	**Neil Croucher**
Utilisation, sawing and milling options, including portable sawmill potential	**Graeme Palmer**
Converting logs to mouldings	**Dick Tomker**
Wood properties, including results of preservation trials	**Graeme Palmer**

11 Appendixes

11.1 Appendix 1: McGregor, A.(Koko Siga) 2009. Prospects for *Endospermum medullosum* (whitewood) from Vanuatu, with particular emphasis on the Japanese market. Economist's report on prospects for whitewood

See attachment

11.2 Appendix 2: Glencross, K. and Viranamangga, R. 2012. Silviculture of Whitewood in Vanuatu (silviculture manual).

See attachment

11.3 Appendix 3: Whitewood poster in Bislama

See attachment

11.4 Appendix 4: Lorum site silvicultural establishment trials

See attachment

11.5 Appendix 5: Brochure on growing whitewood

See attachment

Draft for discussion

Prospects for *Endospermum medullosum* (whitewood) from Vanuatu, with particular emphasis on the Japanese market

Project *Improved silvicultural management of Endospermum medullosum (whitewood) for enhanced plantation forestry outcomes in Vanuatu.*
ACIAR Project Number : FST/2005/089 -

Prepared by Koko Siga (Fiji) Ltd.

December 2009

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Acronyms

ACIAR	Australian Centre for International Agriculture Research
CDM	Clean Development Mechanism
DPJ	Democratic Party of Japan
GHG	Green House Gas Emissions
FSC	Forest Stewardship Certification
ITTO	International Tropical Timber Organization
LCA	Life Cycle Assessment
JLR	Japan Lumber Report
LEED	Leadership in Energy and Environmental Design
NACCC	Vanuatu's National Advisory Committee on Climate Change
MDF	Medium-density fibreboard
NWFP	Non-wood forest products
PEFC	Programme for the Endorsement of Forest Certification
PIC	Pacific Island Countries
REDD	UN – Reducing Emissions Deforestation and Forest Degradation in Developing Countries
RTT	Reforest the Tropics Inc.
SPC	Secretariat of the Pacific Community
SPWP	Secondary Processed Wood Products
VCCP	Vanuatu Carbon Credits Project
VOCGA	Vanuatu Organic Cocoa Growers Association

Exchange rates

Vatu per unit of foreign currency (mid market rate)

	USD	AUD	FJD	JPY
Nov 22, 2009	96.00	86.3	50.0	0.9438

Source: Universal Currency Convertor

Acknowledgements

This market study is primarily based on a desk survey conducted by Andrew McGregor and Kalara McGregor from Koko Siga (Fiji) Ltd. Kalara McGregor visited Tokyo in April 2009 and meet with Mr. Norikuni Yoshida, Managing Director of TransAsia Partners Limited and Mr. Michimasa Mochizuki. Arrangements for meetings with buyers was provided by Mr. Tadamichi Shiramatsu (Deputy Director, Pacific Islands Centre, Tokyo). Lex Thomson and Sairusi Bulai from the EU/SPC FACT Project provided helpful advice and information. Tim Martyn and Rajhnael Deo from SPC provided a range trade statistics. The assistance and support of all these people is gratefully acknowledged.

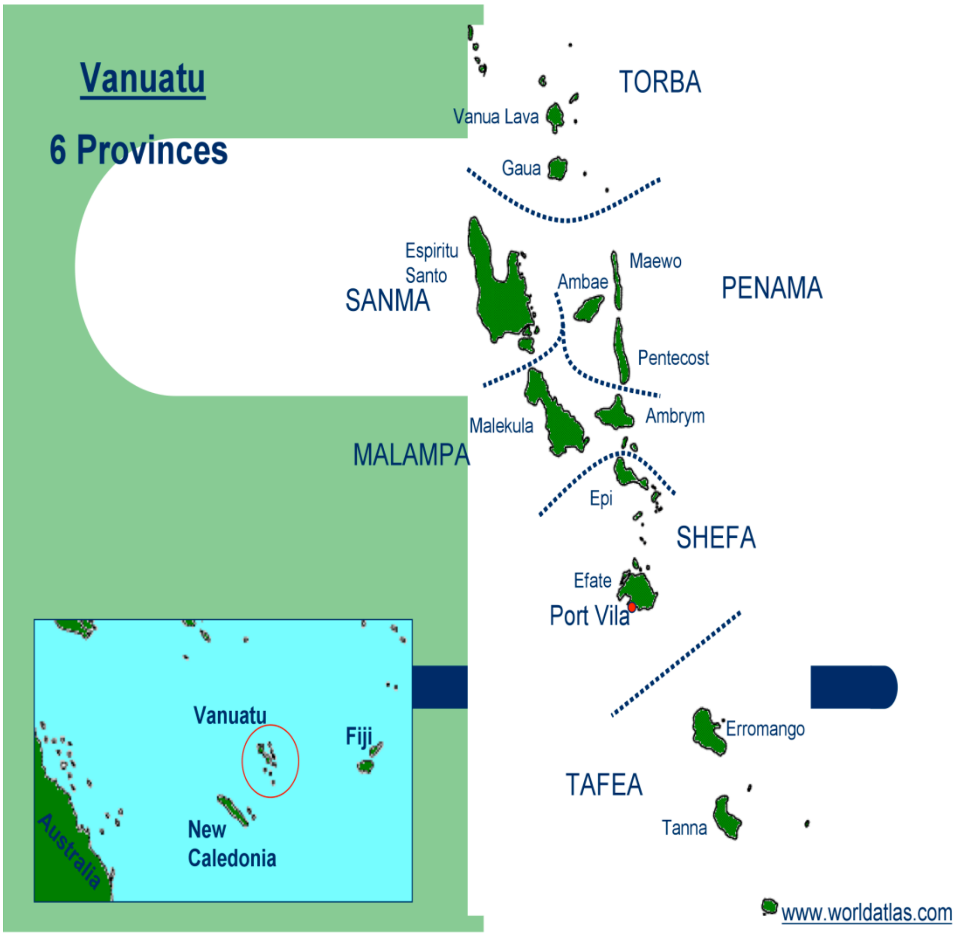
1 Introduction

Whitewood *(Endospermum medullosum)* has been identified as a timber species with strong forestry plantation and agro-forestry potential in Vanuatu and the South Pacific region (Thomson 2006). Good timber properties, together with moderately rapid growth and high cyclonic resistance, make whitewood a particularly suitable species for forestry plantations in Vanuatu (Vutilolo *et al.* 2005).

In the Pacific region, whitewood is distributed from West Papua, through Papua New Guinea, the Solomon and Santa Cruz Islands through to Vanuatu. In Vanuatu, whitewood is found on most islands north of and including Erromango (figure 1). These include Vanua Lava and Gaua in the north, Espiritu Santo, Malo, Maewo, Ambae, Pentecost, Malekula, Paama, Epi, the Sheperd Islands and Efate (Thomson 2006).

Over the last two decades, whitewood logging from natural forests has been an important economic activity in Vanuatu. Most of this timber was exported to Japan and other Asian countries. However, following extensive logging through the 1980s, particularly on the island of Espiritu Santo, Vanuatu's accessible whitewood resource in native forest has been virtually exhausted and there have been no exports in recent years.

Figure 1. Map of Vanuatu



Vanuatu is noted as being the international leader in the establishment of whitewood as a plantation species. By far the largest plantation is the 300 ha established by Melcoffee Sawmill in 1993 at Loro. In early 2008 the ACIAR Whitewood Project measured 27 permanent 0.1 ha whitewood plots across Santo in various woodlots. The are more small plantings scattered across Santo. Vanuatu Organic Cocoa Growers Association (VOCGA) are establishing their own demonstration cocoa plantation in North East Malekula, where whitewood will be used as a shade tree (15 to 20 m spacing) instead of coconuts (McGregor and Watas 2009)[1]. However, current plantation practices are noted as generally

---

[1] This decision is based on the value of the whitewood timber – harvested at 15 to 20 years as a measure to reduce the impact of rats. Coconuts have been identified as a major factor in attracting rats.

poor, 'seriously reducing the economic returns to landowners and preventing the development of a more substantial export market and sophisticated processing industry' (ACIAR 2008).

The prohibition of round log exports by the Vanuatu government in the late 1980's, resulted in the development of a local processing industry. In a joint venture with Melcoffee Sawmill Neil Croucher, re-conditioned second hand machines that were supplied by Mr. Norikuni Yoshida (TransAsia Partners) , to develop a processing industry on the island of Espiritu Santo. To an extent, the machinery and skill set of the operators determines the product that can be exported to Japan – currently the demand from Japan is for 'Main Board' or large rectangular panels of roughsawn timber. The ban on round leg exports has been maintained by the Vanuatu government with the aim of facilitating employment opportunities and value-adding timber products, prior to export.

As a contribution to the ACIAR) Project, *Improved silvicultural management of Endospermum medullosum (whitewood) for enhanced plantation forestry outcomes in Vanuatu*, this report will analyse the market prospects for whitewood from Vanuatu in Japan and elsewhere, including substitutes of other wood and non-wood materials. Virtually all of Vanuatu's exports of whitewood have been to Japan and hence it is the main focus of this study.

2 Timber trade in the Vanuatu economy

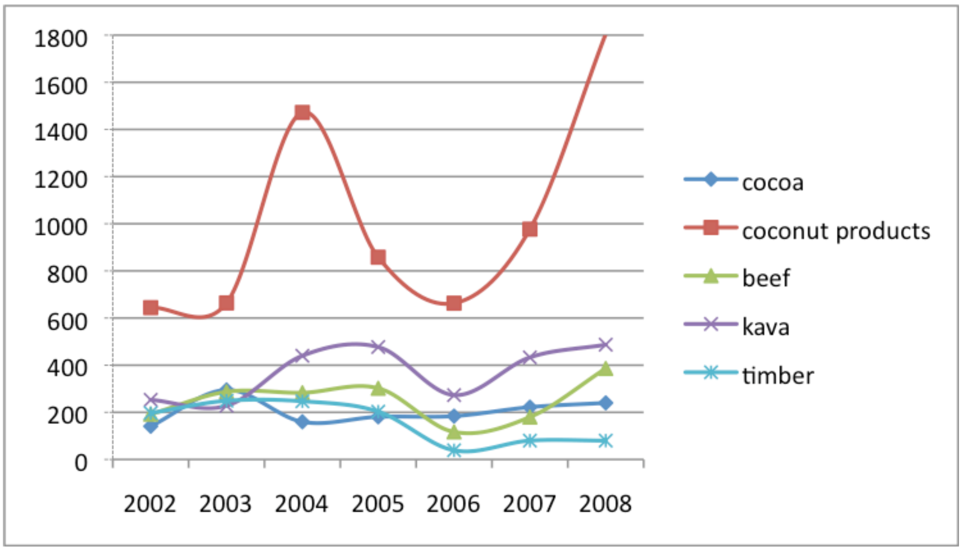
Through the mid 1990s, the value of forest products exported more than doubled, from Vt 255 million in 1994 to Vt536 million in 1999, contributing to 13% of total GDP in the same year (Lui & Tabi, n.d). Following 2000, the increasing scarcity of whitewood in natural forests and the cessation of Malaysian logging companies in early 2000, resulted in contributions to GDP dropping to 7.7% in the same year (ITTO, 2005).

2.1.1 Timber exports

The last decade has seen timber track as a minor export commodity for Vanuatu, in comparison to other agricultural products. Figure 2 outlines how timber has compared to other export commodities from 2002-08. Timber exports have declined sharply in recent years, while other commodities have shown growth. In 2003, timber exports represented 14.5% of total exports. By 2008, timbers share of total export earnings had fallen to 2.5%.

Figure 2. Vanuatu exports in value terms 2002-08 (million vatu)*

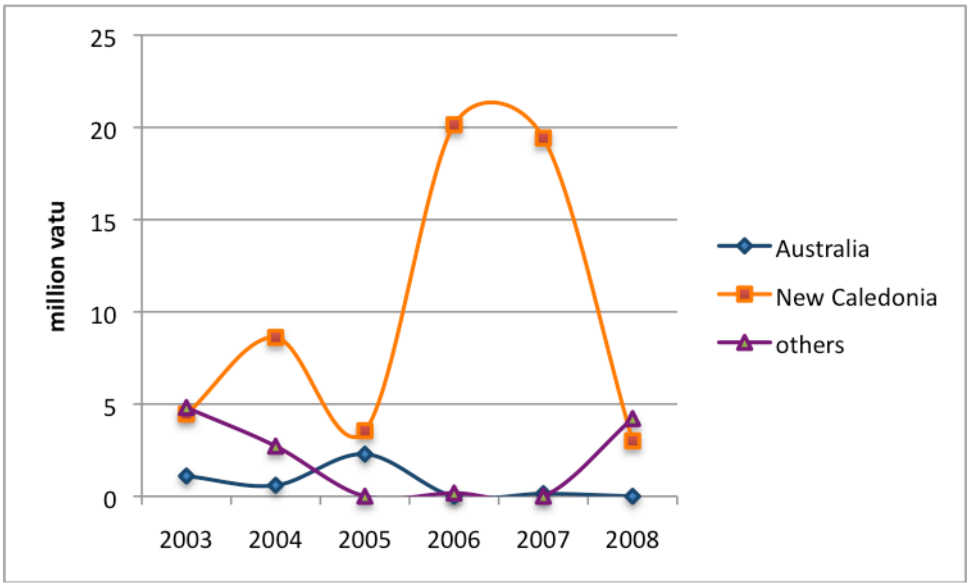
	2002	2003	2004	2005	2006	2007	2008
cocoa	141	295	160	181	184	222	240
coconut products	644	664	1472	858	663	977	1805
beef	192	287	283	302	117	180	386
kava	253	228	440	477	273	433	487
timber	**197**	**249**	**247**	**203**	**39**	**80**	**80**



source: Reserve Bank of Vanuatu Quarterly Reports

Vanuatu's total timber exports to various destinations over the period 2003-08 are shown in figure 3. Over the period, New Caledonia has been the dominant market.

Figure 3. Value and destination of Vanuatu timber exports 2003-08

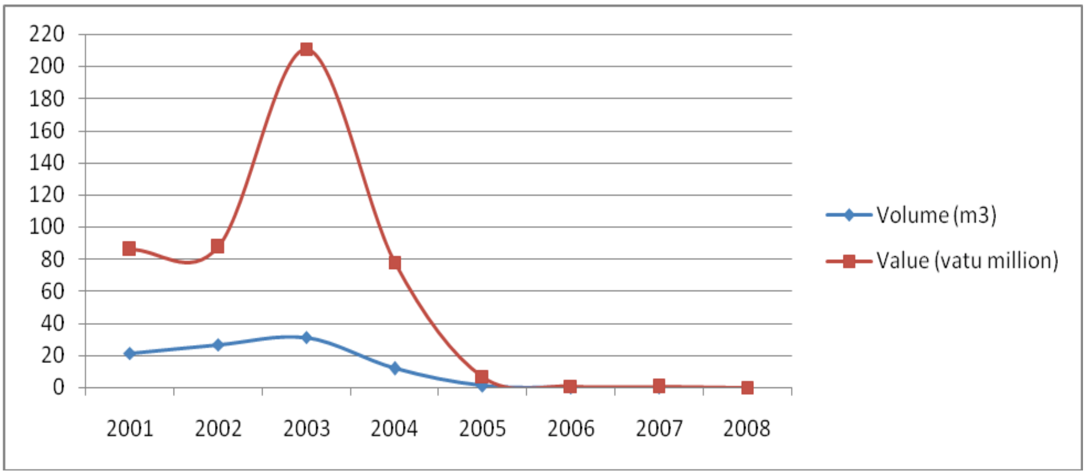


source: SPC Regional Trade Statistics Database

2.1.2 Timber exports to Japan

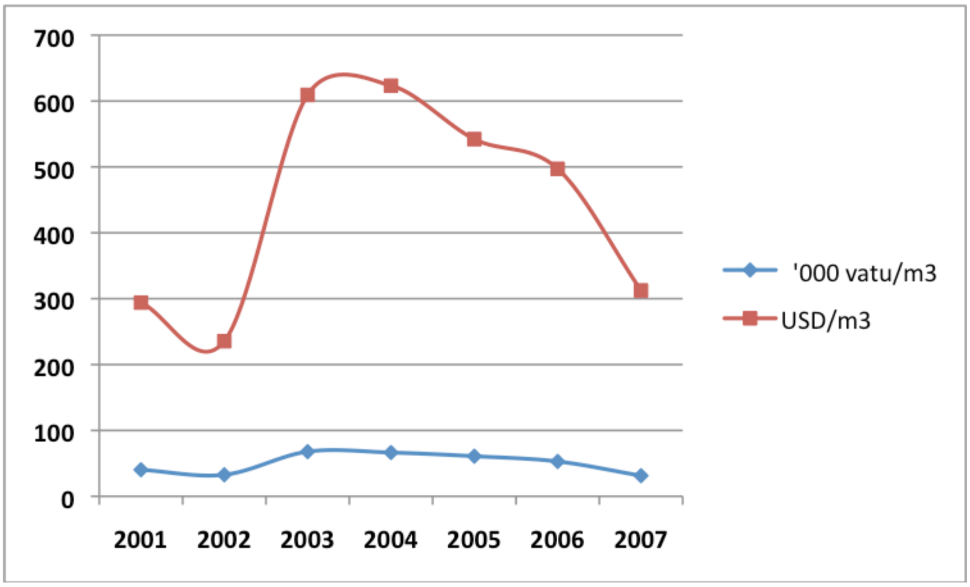
Trade data, supplied by the Secretariat of the Pacific Community (SPC), shows the volume and value of Vanuatu timber exports to Japan for the period 2001-08. The data is for Japan HS categories 440.724 and 440.729. These categories include an assortment of sawn timber species. However, it is assumed that whitewood makes up the major component of these exports. These are plotted in figure 4. The fob value of these exports is presented in figure 5. After peaking in 2003, with 3,100 m3 exported for an fob value of 210 million vatu (68,000 vatu/m3 or USD 609/m3). The average fob price for these exports over this period was 50,000 vatu/m3 or USD 445/m3. There have been no Vanuatu timber exports to Japan since 2007.

Figure 4: Vanuatu timber product exports to Japan 2001 – 08



source: SPC Regional Trade Statistics Database

Figure 5: The value of Vanuatu sawn timber exports to Japan (fob) 2001-07

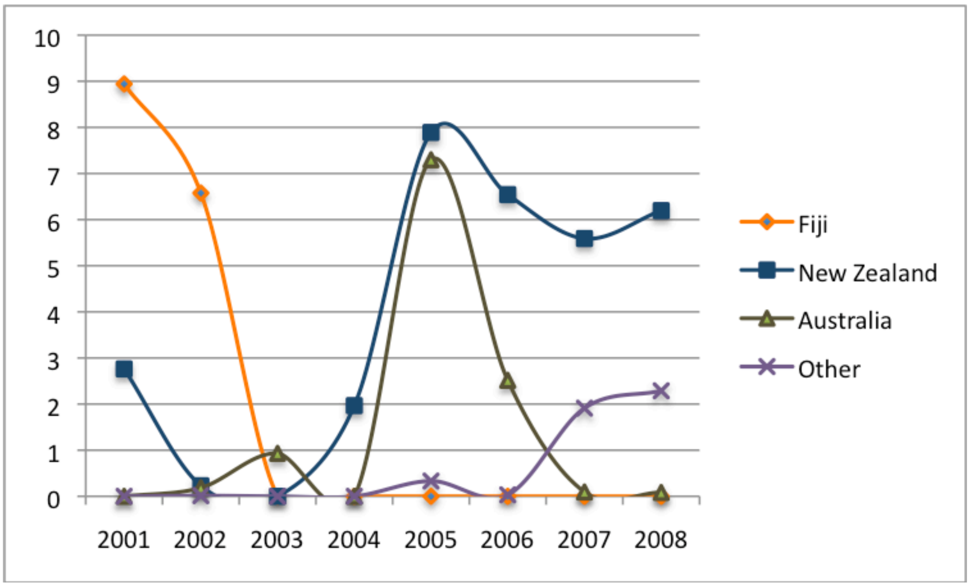


source: SPC Regional Trade Statistics Database

2.1.3 Timber imports

Vanuatu timber imports and their source over the period 2002-08 is shown in figure 6. Radiata pine from New Zealand has been the main timber imported and is now the dominant timber used in the domestic construction industry. The dominance of radiata pine is a relatively recent phenomena. As recently as 2004, virtually all timber used in the construction industry was sourced locally.

Figure 6: Value and source of Vanuatu timber imports, 2002-2008 (million vatu)*



source: SPC Regional Trade Statistics Database

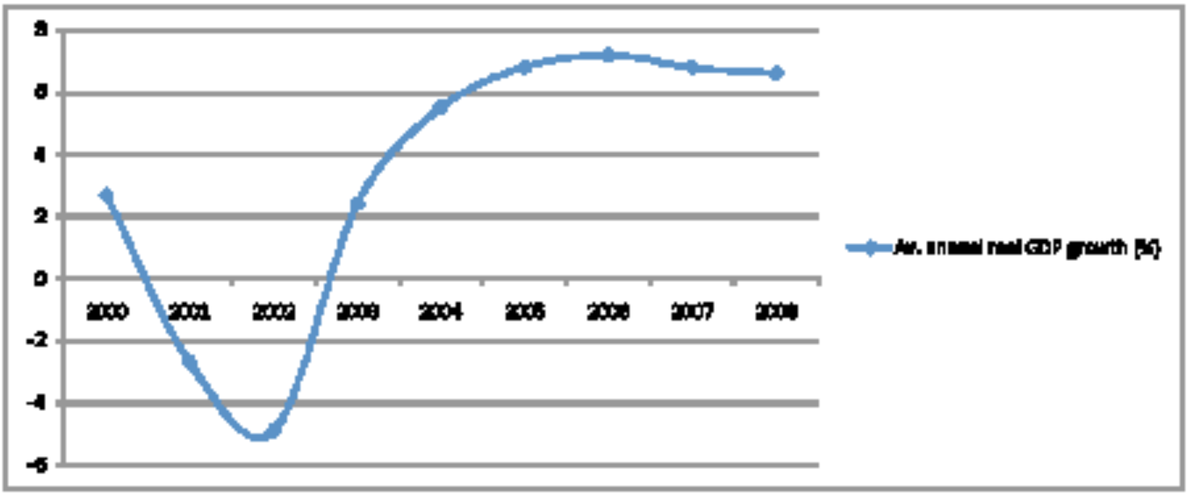
Since 2004, Vanuatu enjoyed strong economic growth and has been the stellar performer among the Pacific Island Country (PIC) economies (table 1). This performance performance is attributed directly to growth in tourism and construction (Howes and Soni 2009). These lead growth sectors were of the view that the highly protected[2] domestic timber industry was unable to meet their requirements and this was constraining the development of tourism and construction. Accordingly, the duty was reduced to 15% in the 2008 Budget. As a consequence, sawn whitewood, even when it is available, is no longer considered competitive with imported New Zealand radiata pine in general light construction purposes[3]. Whether a substantial future plantation based whitewood industry could compete with imported radiata pine, without significant protection, remains to be seen. The future of the whitewood industry largely lies with selling to export markets where the timber's particular attributes can command price premiums which are not available as a general light construction timber sold on domestic markets. The local market for quality lighter coloured timbers for interior application is not sufficiently large upon which to base an industry.

[2] At January 2010, the duty rate on sawn timber is 15%, do from 40% in 2008.

[3] In Nov 2009, radiata pine was retailing for 85,000 - 90,000 vatu/m3 in Santo. Rough sawn whitewood was retailing for 70,000 - 75,000 vatu per m3., with a wholesale price of 45,000 – 60,000 vatu/m3(source: Brad Wood Santo Hardware, John Schick Veneer Logging Ltd.)

Table 1. Vanuatu real growth and inflation, 2000-08

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Av. annual real GDP growth (%)	2.7	-2.7	-4.9	2.4	5.5	6.8	7.2	6.8	[illegible]
Av. annual inflation rate (%)	2.5	2.3	2.3	2.9	[illegible]	[illegible]	1.8	4.1	[illegible]



source: Reserve Bank of Vanuatu Quarterly reports (various issues)

3 An overview of export market prospects for high value timber products

3.1 The projected supply and demand situation

Morell (2001) summarises the consensus of 12 FAO staff on projected supply and demand for forest products by 2050:

> **Demand for most forest products will continue to increase, at least for the next 20 years, and may even increase much more rapidly than current projections suggest.** Shortage of non-renewable primary sources of raw material (gas, petrol) will increase the use of wood products worldwide. **Supplies for major wood forest products (pulp, paper, furniture) will increasingly come from plantations.** Supply of all major wood products will be adequate because of technological improvements, recycling and substitution. **Prices of utility or commodity wood will be similar to or lower than present prices in real terms.**
>
> Supply and demand for major forest products will continue to be centred mainly in developed and a very few developing countries. Wood - not in solid form but in composite panels and other forms - will be increasingly used for house building. Fuelwood will have gained in importance for industrial heating. Non-wood forest products (NWFPs) will diminish in importance, while demand for forest services such as recreation will increase.
>
> More wood will be requested, but more of it will be in the form of wood fibre. There will be increased demand for composite boards, less for sawn timber and face veneer. **Solid wood will be at a premium, especially rare, high-quality hardwood grown in tropical natural forests. Prices of these timbers will be very high and international trade will be strictly controlled by private stewardship organizations.**
>
> Pulp and paper recycling rates will stagnate, perhaps at about 60 to 70 percent of the materials, because of collection costs and availability. There will be no significant reduction in demand for packaging, rather demand will increase with population growth and higher cultural levels, including increased literacy efforts; there will be more electronic commerce but products will still need to be shipped and packaged. Demand for office paper may be down somewhat because of electronic communications.
>
> China, the Russian Federation, Brazil and Australia are some of the countries that will have a leading role in the supply of wood for international markets.

The validity of FAO projections remains – what has changed is the addition of the potential marketable carbon value from planting trees as well as global developments in wood energy. Factors associated with energy efficiency, supply location and climate change policy will be key to wood energy development (FAO 2008). A 2008 FAO Forestry paper notes that the contribution of forestry to future energy production will be influenced by:

- the competiveness of wood-based energy in achieving the objectives of recent energy-related and greenhouse gas reduction policies; and
- the costs and benefits of wood-energy related systems and technologies in social, economic and environmental terms.

In countries where agricultural crops are favoured over trees, forestry would likely be restricted to efficiency gains in current uses as well as increasing the use of wood residues from existing forestry operations (FAO 2008). Under this scenario, the availability of wood for bioenergy production would more likely be controlled by trends in roundwood production, the extent of forest resources and demands that compete for wood residues, rather than world energy markets (FAO 2008).

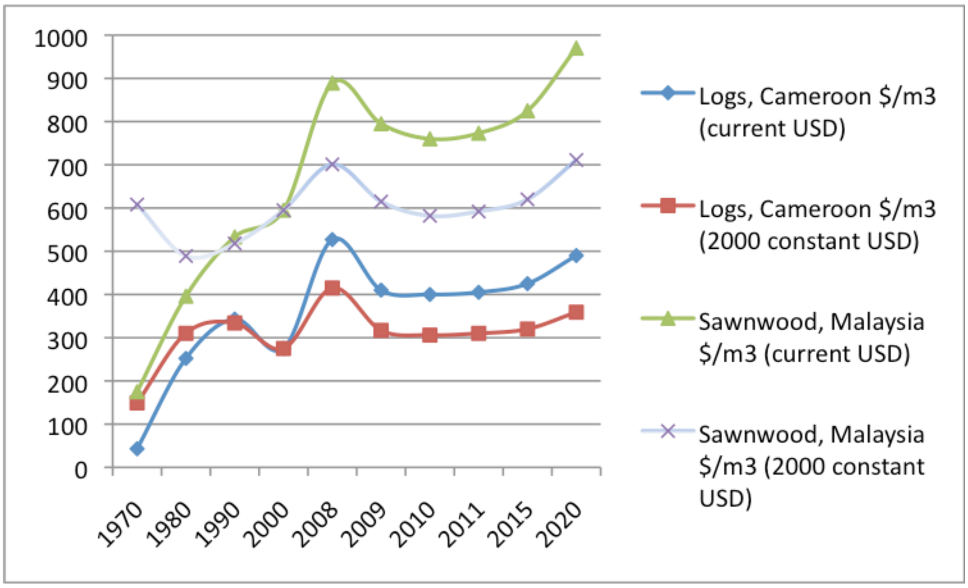
Globally, wood residues provide the most immediate opportunity for wood-energy generation, based on their availability, relatively low-value and the proximity of production to existing forestry operations (FAO 2008). However, many countries lack clear assessments of the quantity of biomass that can be collected from forest operations. In the Vanuatu context, a 2007 SPC/ITTO report observed that the largest fixed mill in Espiritu Santo was utilising some wood waste to produce steam for kiln-drying operations (Adams 2007). Adams was of the view that if the Vanuatu sawmilling sector "where large enough to provide sufficient wood residues, then there are opportunities for power generation which may be at a level that power can be sold to national power companies and fed into the national grid" (Adams 2007). Such wood residue utilisation would require large quantities to be financially viable – these quantities would potentially be available, as by-products of an expanded whitewood plantation industry.

These long-term projections give confidence to investors in the Vanuatu whitewood industry that good quality timber, produced in sufficient volumes, will become an increasing valuable commodity in international trade.

3.2 Global movements in timber prices

Internationally whitewood is a minor niche timber product for which price series data is not available. The World Bank uses the price of Cameroon logs and Malaysian sawnwood as a proxy for timber commodity prices on global markets. The assumption is that there is a reasonably high correlation in the price of all timber products. Figure 7 plots the price of Cameroon logs and Malaysian sawnwood in nominal and real (2000 prices) terms since 1970. World Bank price forecasts for these products through to 2020 are also presented. The 1970s saw a decline in the real price of sawnwood, while the real price of logs increased. The decade of the 1980s saw an increase in the real prices of both logs and sawnwood followed by a decline in the 1990s. The current decade saw a sharp reversal in this downward trend. Real timber prices peaked at historical levels in the 3rd quarter of 2008. This was the height of the global commodity boom, when Cameroon logs reached USD 549/m^3 and Malaysian sawnwood USD 900/cm^3. However, the boom in timber prices was relatively much lower than for most other commodities (figure 7). With the onset of the global recession, timber prices have substantially subsided – although the decline has been much less than most other commodities. By June 2009, the price of Cameroon logs had fallen to USD 406/m^3, a price still well above the average price of 2007 of USD 381/m^3 (World Bank 2009). The June 2009 price of Malaysian sawnwood was USD 819/m^3, compared with an average price of USD 806/m^3in 2007.

Figure 7: Timber prices and forecasts, 1970 – 2020



source: World Bank (2009)

The 2001 to 2007 fob values for Vanuatu's trade sawntimber exports to Japan presented in figure 5 suggest that Vanuatu whitewood received prices significantly below that received by Malaysian sawnwood.

Real sawnwood prices are forecast to stabilise at around the 2000 level for the next few years returning to the level achieved in 2008 by 2020. Real log prices are also forecast to stabilise at around their 2000 level. However, log prices are not expected to return to their peak of 2008 by 2020.

In figure 8, the real timber price index is compared with other commodities over the same 30-year period. Timber, of all the major non-mineral commodity groupings, has proved to be by far the most stable. As with all commodities, timber prices peaked in 2008. However, the boom in timber prices was relatively modest when compared with energy and major agricultural commodity groups of relevance to Vanuatu. The World Bank real price indices in 2008 (2000 = 100) were:

- **Timber 119**
- Energy 270
- Beverages (which includes cocoa) 166
- Fat and oil (which includes copra and coconut oil) 219
- Grains (imported rice and wheat flour for food security) 222

The subsequent decline in real prices for timber has been less for timber than most other commodity groups. The World Bank real price indices in 2009 (2000 = 100) were:

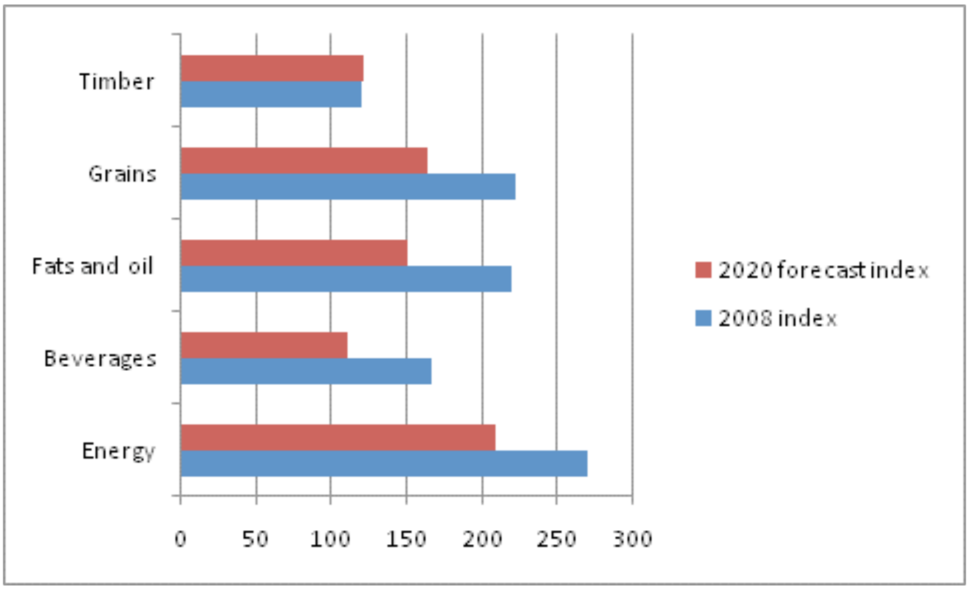
- **Timber 106 (decline 13 from in 2008)**
- Energy 138 (decline 132)
- Beverages 154 (decline 12)
- Fat and oil 156 (decline 63)
- Grains 160 (decline 62)

However, the 2009 real price index for timber products was still well above the 2000 base level.

Over the next few years, real timber prices are expected to remain at current levels and then steadily increase to return to their 2008 level by 2020. In comparison, none of the real prices of the other commodity groups of interest to Vanuatu are projected to return to the heights experienced in 2008 (figure 8).

Figure 8. A comparison of the real price index for 2008 with the 2020 forecast (2000=100)

	2008 index	2020 forecast index
Energy	270	209
Beverages	166	110
Fats and oil	219	150
Grains	222	163
Timber	**119**	**121**



source: World Bank (2009)

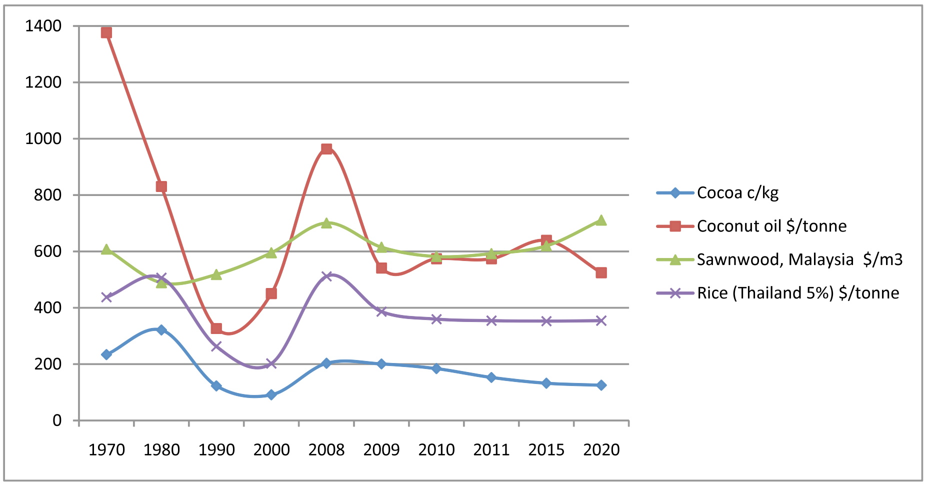
Price time series data for Malaysian sawnwood is probably the best available broad proxy for Vanuatu whitewood. In Figure 9, the actual and forecast real prices for Malaysian sawnwood over the period 1970 to 2020, are compared with Vanuatu's main agricultural export commodities (coconut oil and cocoa) and agricultural import commodity (rice).

Over this 30-year period, the real price of sawnwood shows generally a steady upward trend. Real prices reached a peak in 2008 and are expected to contract somewhat for the next few years before returning to their upward trajectory. This relatively stable long-term upward price trend for sawnwood is in marked contrast to that of Vanuatu's major commodities. Coconut oil, the main export commodity has experienced wide price fluctuation over the last few decades – with extreme real price peaks experienced in the 1970s and in 2008. Prices have substantially subsided from their 2008 level, but still remain above the extremely depressed levels of the 1990s. Real cocoa prices are currently enjoying a revival from the depressed prices of the 1990s. However, real cocoa prices are projected to trend steadily downwards over the next decade. Rice plays a crucial role in Vanuatu's food security – with rural communities producing copra and cocoa for export and importing rice. Real rice prices fell significantly through the 1980s to the early 2000s. The 2008 commodity boom saw a dramatic increase in rice prices. Although these prices have since subsided, they remain at historically high levels and are forecast to remain at this level for the next decade.

Investors in the growing and processing of whitewood can draw some confidence from this long-term price data. The data shows that they would be investing in a commodity that has experienced a steady increase in real prices over three decades and which are expected to continue to increase into the future. In contrast, coconut oil faces a much more uncertain price future and cocoa faces a scenario of declining real prices.

Figure 9 Real sawnwood prices compared with Vanuatu commodity prices (constant 2000 USD**)**

	1970	1980	1990	2000	2008	2009	2010	2011	2015	2020
Cocoa c/kg	234	321	123	91	203	201	184	153	132	125
Coconut oil $/tonne	1376	831	327	450	964	541	574	574	639	524
Sawnwood, Malaysia $/m^3	**608**	**489**	**518**	**595**	**701**	**615**	**582**	**592**	**620**	**711**
Rice (Thailand 5%) $/tonne	438	506	263	202	512	387	360	354	353	354



source: World Bank (2009)

Globally, Japan is a leading importer of tropical timber products, particularly plywood. Up until the early 1960s, Japan was largely self-sufficient in terms of wood supply. Within a decade, Japan became the largest log-importing nation, with the rapid transition brought about by factors such as the high cost of domestic harvesting, and a shrinking workforce in the domestic forestry sector (Cohen & Gaston 2001). During the 1980s, a second transition occurred, with supplying regions, such as Vanuatu, restricting log exports due to domestic demand or policies that encouraged value-added processing. This ran concurrent with increasing domestic demand in Japan, due to high levels of housing starts and a strengthening yen. The result in Japan was that domestically produced sawnwood, produced from imported and domestic logs, was replaced with imported sawnwood. Domestically produced plywood, produced largely form imported logs, was also replaced by imported plywood. Japan now imports three major product types: sawn timber, softwood logs and plywood.

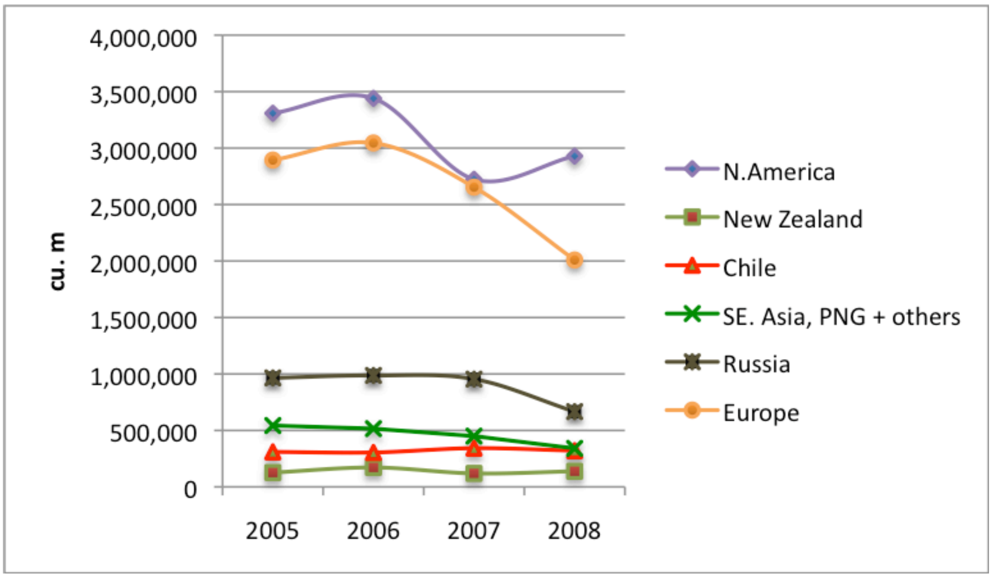
In the context of interior application, recent years have seen a growing trend in the Japanese market for non-structural wood products, largely driven by increasing consumer demand for use of light coloured softwoods (Cohen & Gaston 2001). With increasing consumer interest in 'healthy, breathing homes,' wood is replacing the use of other materials such as steel and plastics in building interiors. The rigorous quality standards that are applied to structural wood products are similarly applied to interior products. These include:

- clear (knot-free) wood;
- large dimensions;
- tight growth rings and;
- uniform colouration (Cohen & Gaston 2001)

In broad terms, Figure 10 indicates a downward trend across all lumber imports into Japan from major origins, from 2005-08. The drop has been most apparent for EU imports, with South East Asia, PNG and other Pacific imports also in decline. Imports from New Zealand and Chile have been somewhat stagnant.

Figure 10. Japanese Lumber imports from major origins 2005-08 (m^3)

	N.America	New Zealand	Chile	SEast Asia, PNG + others	Russia	Europe
2005	3,308,459	126,862	309,828	543,276	964,880	2,893,922
2006	3,440,554	171,829	304,736	515,822	986,702	3,045,429
2007	2,723,683	119,485	343,023	449,584	954,123	2,653,820
2008	2,929,211	138,283	320,853	341,021	666,457	2,009,161



source: Japan Lumber Reports, 2009

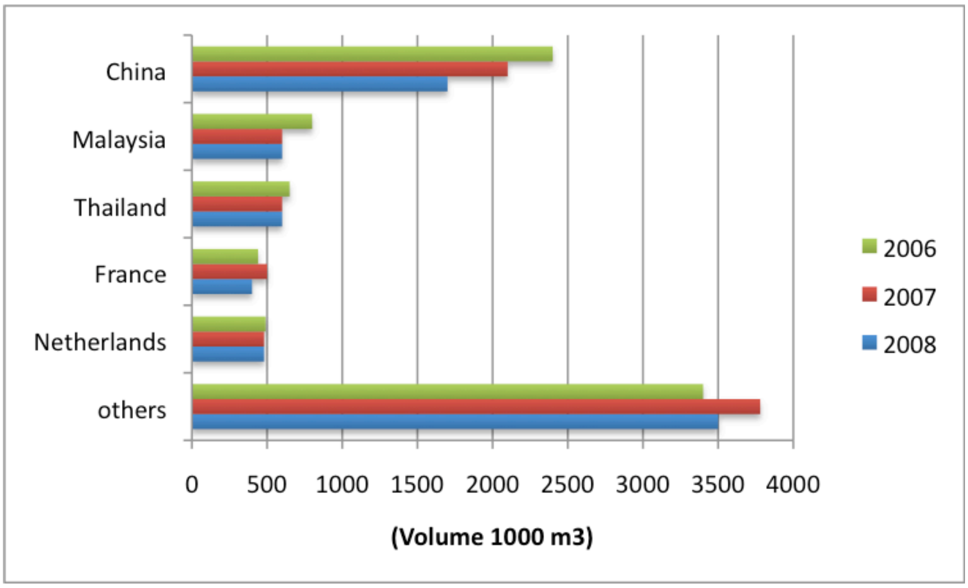
3.3 The market situation and trends for timber used for sawnwood

ITTO reports note that Japan's tropical sawnwood consumption has been in continuous decline for several years to 2007 - it is estimated to plummet further to 238 000 m3 in 2008, down 46% on 2006 levels (ITTO 2008). This decline is due largely to the country's slowing economy, solid competition from imported softwoods and in recent times, the increasing availability of domestic log supplies (ITTO 2008). In the medium term, Japan's grim economic outlook following the 2009 financial crisis as well as protectionist inclination of Japan's recently elected government is likely to further reduce consumption.

3.3.1 Global trends in tropical sawnwood imports

Figure 11 outlines major ITTO importers over 2007-08 of tropical sawnwood, ranked according to 2007 import volume. According to ITTO statistics, Asia, particularly China, dominates tropical sawnwood imports. China's imports in 2007 were 2.1 million m3 (ITTO 2008). China's primary tropical sawnwood suppliers in 2007 were within the SEast Asia region – an estimated 60% collectively from Thailand, Indonesia and Malaysia. Malaysian imports were similarly predominantly from Indonesia and Thailand. It is interesting to note that the decline in EU imports of tropical sawnwood is attributed to factors including: a lack of certified timber (UK-specific) and changing consumer tastes towards lighter-coloured timbers (ITTO 2008). Both of these factors represent a potential opportunity for plantation whitewood from Vanuatu. The large 'others' category is indicative of the diversified nature of the global tropical sawnwood market – with ITTO reports noting an increasing trend in the EU for countries to purchase tropical sawnwood indirectly, via stockpiles in Belgium, Netherlands and Luxembourg, thus decreasing direct purchasing with producing countries (2008).

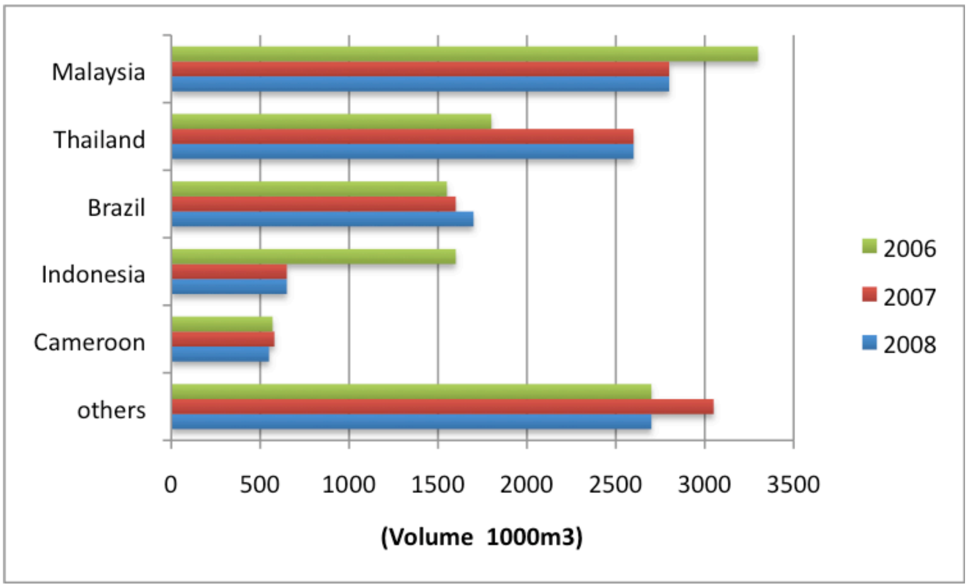
Figure 11. Major ITTO importers of tropical sawnwood 2006-08



source: derived from ITTO 2008

Figure 12 outlines major ITTO exporters of tropical sawnwood from 2006-08, based on 2007 volumes. Within this listing is Cameroon, a major exporter of *Triplochiton scleroxylon*, also known as African Maple or according to the African country of origin, Ayous, Wawa or Obeche. African Maple is perhaps the timber closest in characteristics to Vanuatu whitewood. African Maple is a light density (370-410 kg/m3) light coloured timber which is considered "not quite as strong as whitewood" by Japanese importers (pers. comm.). Cameroon exports are mainly to Europe, including France, Spain, Italy, the Netherlands and the United Kingdom. ITTO reports anticipated a decline in Cameroon exports in 2008 with demand and price in the EU moving downwards (2008).

Figure 12. Major ITTO exporters of tropical sawnwood 2006-08



source: derived from ITTO 2008

3.3.2 The market situation and trends for timber used for veneer and plywood

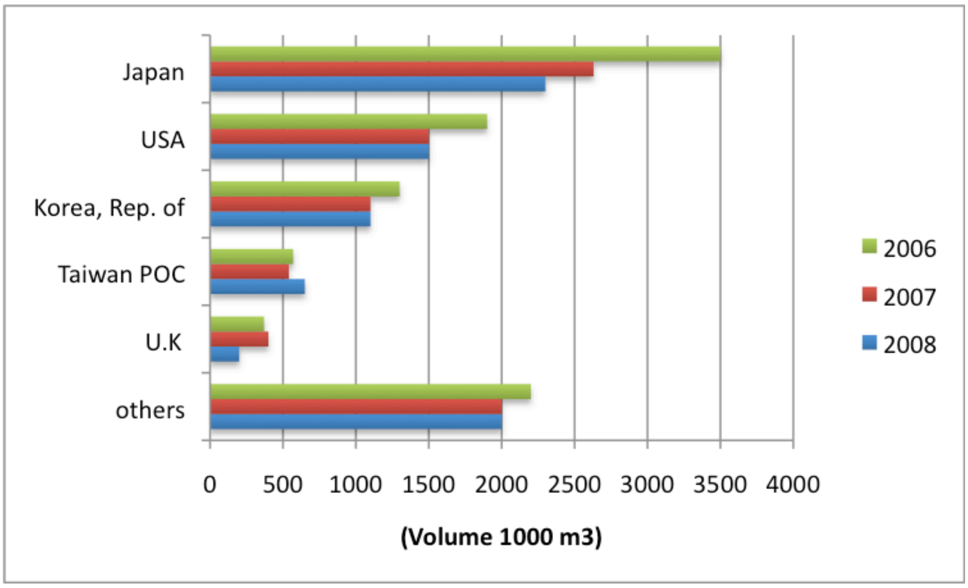
Japan

In broad terms, temperate softwood plywood tends to be inherently of lower quality, compared to tropical plywood with more knots or wide growth rings in temperate softwoods, such as fast grown radiata pine. As such, consumers still prefer to use tropical over temperate softwood, where a smooth and attractive appearance is required. Tropical softwoods such as Vanuatu whitewood, PNG Basswood and African Maple meet these appearance requirements. 'Combi-plywood' is a common product in Japan. The face and back veneers are usually from tropical logs and the core veneers are peeled from softwood logs. In Japan, combi-plywood producers generally utilise larch, a softwood from Russia for the core veneers, with tropical logs from Malaysia and PNG used for the face and back veneers (ITTO 2008). When supply was available, Vanuatu whitewood was also used for face and back veneer purposes.

Japan has consistently led the world in tropical plywood imports. Figure 13 shows the major ITTO plywood importers, ranked by volume for 2006-08. While Japan remains the leading tropical plywood importer, these imports have fallen sharply in recent years.

The last decade has also seen a sharp drop in Japan's own tropical plywood production. Japanese production fell to 625,000 m3 over 2004-06, amounting to an 82% decrease from 1995 levels (ITTO 2007). This decline has continued through to 2008. Similarly, Japan's tropical veneer production has dropped by two thirds since 2001, with its tropical veneer and plywood industries contracting due to declining log availability, and its stagnant economy during most of that period. Extending into 2009, Japan Lumber Reports note the depressed plywood market in Japan has resulted in a marked drop in log imports from the Asia Pacific region – specifically, Indonesia and PNG imports each fell just under 60% during the first half of 2009 and Solomon Islands' imports fell an estimated 24%, from the same period in 2008 (ITTO 2009a).

Figure 13. Major tropical plywood importers 2006-08



source: derived from ITTO 2008

Recent market developments in Japan

In July 2009, Japan Lumber Reports (JLR) noted that housing starts were down by 32% over the previous year (JLR 2009a). Wood based units comprised 57% of total housing starts. As a consequence:

- plywood imports had fallen by 26.6% over the year
- Japanese South Sea plywood mills have reduced production by 20-30%.

JLR also reports that imports of South Sea logs were down by 50% during the first half of the year, reaching a volume of 354,318 m3. The main reason for this decline was the depressed plywood market in Japan.

Other trends to note in the Japanese market include plywood manufacturers increasing the proportion of softwoods used in plywood and veneer production. Japan is also experimenting with lamination and 'direct-print' techniques to allow the re-use of concrete form plywood panels. Japanese plywood manufacturers have begun establishing joint ventures for plywood and other panel products in producer countries where costs are more competitive (ITTO 2009b). This offers a potential market opportunity for a Vanuatu processor. However, as noted by market sources in Japan, quality of existing finger jointing and glue panelling produced in Vanuatu would need to improve considerably.

Global trends

Over the last few decades, timber veneers and plywood have become more widely used, particularly in furniture manufacture. This global trend has been largely driven by the increasing cost and difficulty in obtaining quality hardwoods.

Since the 1990s, the ITTO note that there has been a significant reorganisation among veneer and plywood producers. In 2005, China became the ITTO's largest tropical veneer producer, overtaking Ghana, Brazil, the Philippines and Malaysia, with a dramatic 13-fold increase from a decade earlier - from 550,000 m3 in 1995 to 4.4 million m3 in 2005 (ITTO 2009a). China's expansion is in line with the demand of its growing construction and export sectors. India's tropical plywood production is also on the rise overtaking Brazil and Japan, at an estimated 2.3 million m3, in volume terms, in 2006 (ITTO 2009b). Both India and China's plywood production are largely based on imported tropical logs. Indonesia's plywood production has been in fluctuation, with production in decline in the years prior to 2004, as a result of logging quotas and increasing controls on illegal log flows. Recent years have seen Indonesia's production rebound, to 6.1 million m3 in volume terms, in 2006 (ITTO 2009a).

3.3.3 The market situation and trends for timber used for Secondary Wood Processed Products (SPWP)

Secondary Processed Wood Products include light construction, joinery, furniture and other interior uses such as cabinetry and wainscoting. All of these are appropriate uses for Vanuatu whitewood. Amongst ITTO producer and consumer countries, wooden 'furniture and parts' amount for an estimated 60% of SPWP trade (ITTO 2008). This is followed by builder's woodwork and mouldings. The United States and Japan are the two largest markets for SPWP from ITTO producers, with such products making up 31% and 22% of their total SPWP markets respectively in 2004(ITTO 2008). However, these shares have declined since 2000, primarily due to competition from China. As with its plywood exports, most of China's SPWP exports are based on imported tropical and temperate logs. The growth in China's SPWP exports is expected to grow with companies from the United States and Southeast Asia continuing to establish joint ventures in southern China; taking advantage of the low costs and policies encouraging downstream timber processing (ITTO 2008). An example from the region is that of Fiji's iconic coconut furniture label, Pacific Green and its relocation of all but its showroom to China.

A number of traditional exporters of primary timber products have begun the progression into SPWP. Cohen & Gaston 2001 reports a rapid growth in SPWP in developing countries largely driven by:

- exporters of primary products wanting to value-add, to increase profits and to decrease vulnerability to cyclic swings in prices; and
- cost competiveness shifting from raw material costs to comparative advantage based on processing costs. As a result, comparative advantage in manufacturing is shifting from western Europe to eastern Europe, Southeast Asia, China, Latin America (Brazil, Chile, Mexico) and Central and West African countries.

Vanuatu with its high formal sector wage structure, relative to productivity, is not expected to have a comparative advantage based on processing costs, unless it can attract substantial capital investment in processing equipment.

4 The structure of the Japanese whitewood timber market

4.1 Trade and trends

Whitewood is a soft, medium density timber in which both heartwood and sapwood have a straw colour that lightens on exposure (Thomson 2006). The texture is even and it is particularly easy to kiln dry and not prone to surface checking (Thomson 2006). In Vanuatu, it is used for light construction, furniture and interior building materials and has potential for veneer and plywood production. Vanuatu Whitewood exports to Japan have primarily been 'main board' panels, primarily for use in the general market. Discussions with market sources in Japan highlighted that Vanuatu whitewood is favoured in the Japanese market for the following primary reasons:

- **Light colour**: this makes the timber easy to stain. Furthermore, Japanese consumer tastes over the last decade have shifted towards lighter coloured timbers for interior application (Cohen & Gaston 2001).
- **Low-medium density**: at an estimated 440 kg/m3, for a mean air-dry density (12% moisture content) this makes whitewood easy to process (Thomson 2006).
- **Easy to dry, in the kiln drying process**: reduction of moisture is easy to control, in comparison to other timbers.
- **High recovery rate:** depending on what is being made, the recovery rate is high, in comparison to other timbers.

From a production perspective, whitewood is favoured primarily due to its:

- **Short rotation**: tropical hardwoods take a comparatively longer time to grow than Whitewood, even in plantations. Japanese market sources noted that whitewood can be harvested "within 15 years, or even 7 years, if the plantation is properly thinned" (pers. comm.).

Vanuatu Whitewood is perceived in the Japanese market as an adaptable timber, particular suited to 'face and back veneer' uses. The main competitors for Vanuatu whitewood in Japan include Papua New Guinea and Central and West African timbers. Specifically from PNG, PNG Basswood and from West and Central Africa - *Triplochiton scleroxylon*, also known as African maple or depending on country of origin, Obeche, Ayous or Wawa. While PNG Basswood has the same botanical name as Whitewood, Japan market sources noted that its 'hardness is slightly different to Vanuatu whitewood' (pers.comm.) African Maple, a light density (370-410 kg/m3) and light coloured timber is well known in the Japanese marketplace and was noted as the favoured substitute for Vanuatu Whitewood. The trade name PNG Basswood refers to several *Endospermum* species, including *Endospermum medullosum*, and at least one other species which has lighter softer wood. This makes PNG basswood a variable and inferior product to Vanuatu whitewood.

Specific trade data of whitewood is difficult to come by. This is a narrow niche timber product that appears in a number of different harmonised tariff system codes – these are mostly:

- 4407.99 500
- 412.99 110
- 4403.49 600

The complexity with sourcing specific trade data on whitewood is that other timber and timber products are lumped together with whitewood at the 6 digit HS code level 4407.99 (an 'other' category for wood that is sawn or chipped lengthwise, sliced or peeled, >6mm thick).

Japanese Bilateral Trade Data for 2009 presents data for *Endospermum medullosum* lumber imports into Japan 2006-08.[4] It shows miniscule imports from Vanuatu and substantial but declining global imports. The Whitewood products described in this table are classified as 'sawnwood products, chipped lengthwise, sliced or peeled, of a thickness exceeding 6mm.' Table 2 outlines the value of Whitewood imports into Japan, from all sources, from 2006-08. While an overall decline is apparent (36% in 2008 from 2006 levels), this data shows that substantial volumes of timber described as *Endospermum medullosum* are being imported into Japan from sources other than Vanuatu. It is likely that world imports includes all *Endospermum* spp. and not just *Endospermum medullosum*.

Table 2. *Endospermum medullosum* lumber imports into Japan 2006-08, in value terms (USD)

	2006	2007	2008
Vanuatu	10,000	19,000	0
World	161,154,000	128,066,000	104,252,000

source: www.customs.go.jp

Discussions with Mr. Norikuni Yoshida, Director of TransAsia Partners Limited, the sole importer of Vanuatu Whitewood products into the Japan and Asian market, confirm that exports tracked 1,000-3,000m3/annum from 1998-2007. These were sourced directly from natural forest resources, with the inclusion of plantation Whitewood, for testing purposes. In 2007, TransAsia Partners Ltd stopped importing Vanuatu Whitewood, due to the suspension of a pilot reforestation program on Santo. Since that time, there have been no further exports of Vanuatu whitewood to Japan.

Mr. Yoshida noted that Vanuatu white wood products were well received in Japan and Asia and believed that exports would soon recommence, with the expectation to harvest both natural and plantation white wood (pers. comm).

4.2 Who are the buyers

There are two distinct segments of the Japanese timber market:

- Building/Housing Manufacture market
- 'General' market

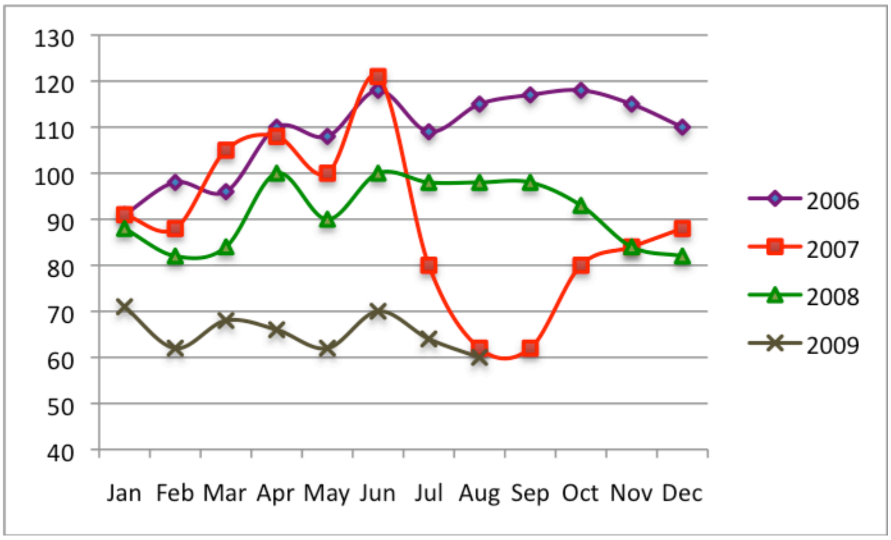
While Vanuatu whitewood has been sold primarily on the 'General' market, both of these segments are described briefly below because to some extent they are interdependent.

4.2.1 Building/Housing Manufacture market

Over the last decade, most of the solid or composite wood used in Japan has been for residential construction, with Japan rivalling the US market in terms of number of housing starts. This market bottomed out significantly over 2007-08. As illustrated in Figure 14, August starts in Japan were down an estimated 40% on the same month in 2008 (ITTO 2009).

[4] www.customs.go.jp

Figure 14: Index of Japan Housing Starts 2006-2009 (,000 units)*



source: derived from ITTO 2009b

With regards to whitewood, the building manufacture market relates specifically to interior application including cabinetry, flooring, panelling, windows, doors and other interior products. Recent years have seen a growing trend in the Japanese market for non-structural wood products for interior application (Cohen & Gaston 2001), largely driven by increasing consumer demand for use of light coloured timbers. With increasing consumer interest in 'healthy, breathing homes,' wood is also steadily replacing materials such as steel and plastics in building interiors (Cohen & Gaston 2001). Given the non-structural usage of whitewood, housing start information does not provide a full picture of trends. Data on housing refurbishments and renovations, which is more difficult to quantify, would provide a clearer illustration of market trends. However, it could be expected that renovations would be closely correlated to housing starts given that they are both driven by income expectations.

4.2.2 General market

The general market, is the primary market for small medium enterprises, and includes the veneer and open lumber markets, or *ichiba.* Vanuatu whitewood 'Main Board' products are sold on this market. The General market has two broad categories for products:

- Construction materials
- Furniture

As described by Mr. Norikuni Yoshida, construction materials comprise 70% of the General market, with lumber sold 'as is.' Furniture materials comprise the remaining 30%, where lumber is generally pre-stained (pers. comm.).

'Main Board', which refers to large rectangular panels of rough sawn timber, produced in the milling process, are graded and priced according to face and back veneer quality. Grading is set in three levels and the '**3 5 50' mm** dimensioning rule for roughsawn timber is applied. Measured in millimetres, the dimensioning is applied as follows: 3mm (thickness) 5mm (width) 50mm (length).

Working off nominal and actual size, the rule is applied as in the following example:

a) **invoice order:** 20/100/1000
b) **actual size**: (that miller must provide) 23/105/1050

Mr. Yoshida noted that facilitating the proper understanding of this rule amongst Vanuatu millers, has been particularly difficult, with much discrepancy in timber sizing. To quote, "sometimes Vanuatu millers supply just the invoice order size, or sometimes, even less. It is very important that millers understand this dimensioning rule" (pers. comm.).

4.2.3 The suppliers of whitewood/and its substitutes

There are a number of timbers considered to be very similar to Vanuatu whitewood. The closest substitutes are timbers from Papua New Guinea and Central and West African countries. Specifically these timbers are:

- ***Endospermum* spp.** or PNG Basswood; While PNG Basswood has the same botanical genus, and includes whitewood, Japan market sources noted that its “hardness is slightly different to Vanuatu whitewood, and Vanuatu whitewood is preferred” (pers.comm.).
- ***Triplochiton scleroxylon*** or African Maple; It is also known as Obeche (Nigerian and Cameroon name) Ayous or Wawa (Ghanaian name).

There are also temperate region timbers with similar physical characteristics. These include:

- ***Tilia americana*, or American Basswood;** American Basswood machines well and is easy to work with hand tools making it a preferred carving wood in the United States. Internet market sources note that it is available in a full range of thicknesses and specifications, although volumes can be limited.[5]
- ***Betula* spp., specifically Baltic/Russian Birch**; Baltic Birch has been a popular plywood product on the US market, noted for its light colour, strength and comparative affordability. While Russian forestry regulators continue to battle with illegal logging practices (Khatchadourian 2008), Baltic Birch is a favoured lumber on the US market for manufacturing furniture dimension components, finger jointed edge glued panels, flooring and mouldings. Baltic Birch easily takes stains; so finished products can range from natural to any colour.

Significant volumes of African Maple, according to ITTO trade statistics, are exported to Japan as round log and sawnwood products from Central and West African sources (2009a). Cameroon is the main source of this timber with Cameroon also exporting African maple veneer and plywood products to Japan. Market sources in Japan identify African Maple, or Obeche, as the closest substitute to Vanuatu whitewood and a species that the Japanese market is familiar with. In terms of its physical characteristics, Obeche has an interlocked grain with fine texture and white to pale yellow colour. Similarly to Vanuatu Whitewood, it is light density (370-410 kg m3) and noted for its face/back veneer qualities by suppliers as a ‘good option for the boxes of cabinets that are faced with a light coloured hardwood’ [6] .

The Cameroon timber export industry is a mature one, with French and Italian logging companies active in the country since the 1950s. Obeche accounts for over 30% of timber exports as a species, from Cameroon (Bikie et al. 2000). Italy is the leading importer, with sawn Obeche accounting for a third of Cameroon timber exports to Italy in 2003. While log exports from Cameroon are in decline with government policy to increase value and processing being progressively introduced, Obeche logs continue to be exported to Japan, mainly to supply the veneer industry (ITTO 2008). In broad terms, the overall market situation in West and Central Africa in early 2009 has been noted as mixed, with production and supply being relatively low and prices affected by low global consumption (ITTO 2009a). For African Maple exports specifically, the primary Western Europe market has seen steady contraction over the last decade as manufacturers either relocate or import mouldings and other semi-finished components from low cost locations in Eastern Europe and Asia (ITTO 2009a). African Maple demand has also been impacted by medium-density fibreboard (MDF) substitution in some European markets (ITTO 2009a).

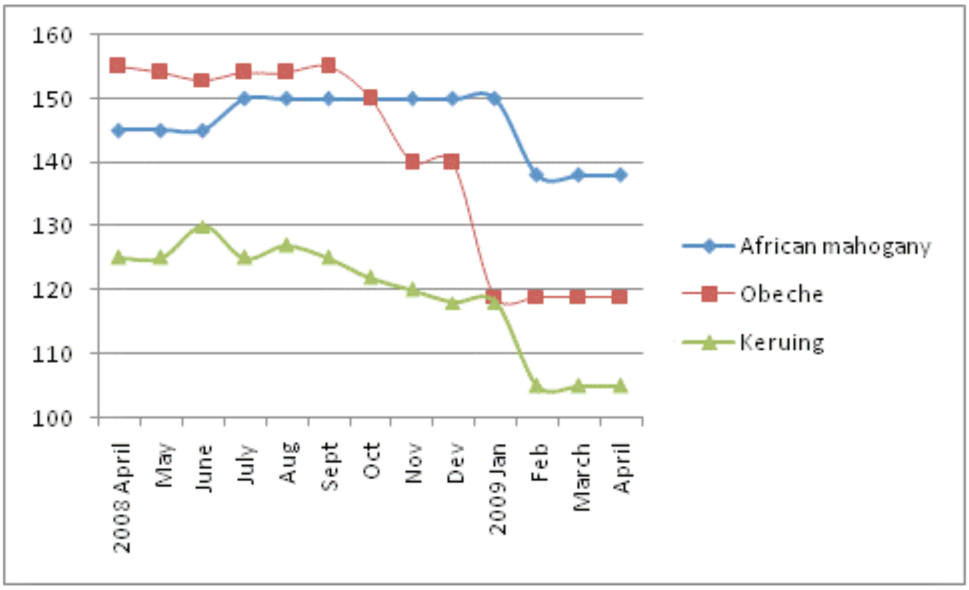
Figures 15 and 16 illustrate price movements in Obeche log and sawn timber fob export prices from over the last year. The log prices have been far more sensitive to the global recession, with the fob export price index falling from 157 (1997=100) in April 2008 to 118 by April 2009. The sawn timber fob price index fell to 140 (1997=100) in late 2008/early 2009 and has since

[5] http://www.hotfrog.com/Products/Basswood

[6] http://www.timbermerchant.co.za/obeche.html

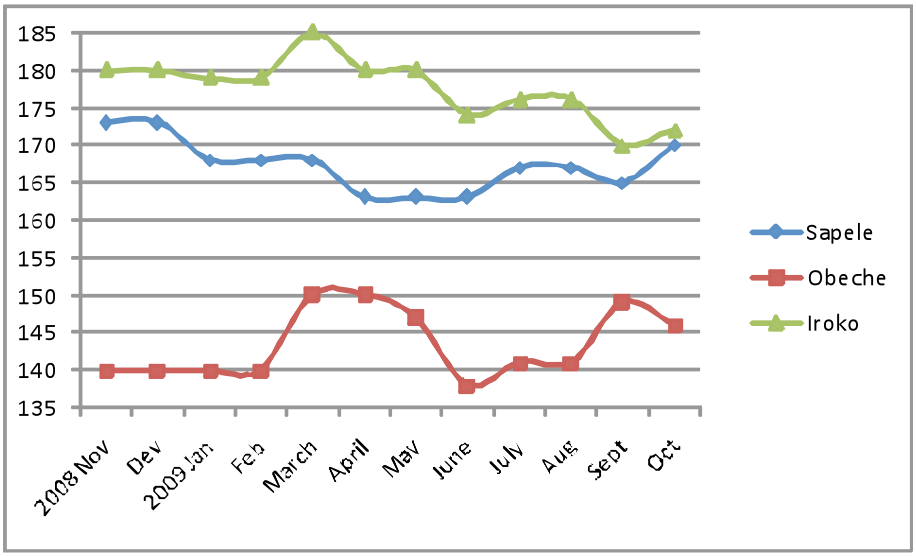
recovered to 150.

Figure 15: Index of tropical log prices (fob West Africa Jan 1997=100)*



source: ITTO (2009)

Figure 16: Index of tropical sawn timber prices (fob West Africa Jan. 1997=100)*



source: ITTO (2009)

5 Vanuatu's capability to meet market requirements

The ban on round leg exports has been maintained by the Vanuatu government with the aim of facilitating employment opportunities and value-adding timber products, prior to export. A 2007 ITTO/SPC-funded report noted that under Vanuatu's present tax and fiscal structure, the value-added component of exported lumber is captured mostly by the processor, with little change in the share captured by either the landowner or the government (Adams 2007). The report further noted that while the attraction of domestic processing is the increased economic activity associated with adding value, it is uncertain whether industry is willing to make the necessary investment in processing "when it is becoming increasingly difficult…to secure regular supplies of round logs for sawnwood production to satisfy domestic & export demand and to satisfy the raw material needs of the fledgling downstream wood processing industries"(Adams 2007). Interviews in Japan confirmed this, with Mr. Norikuni Yoshida noting that the reconditioned, second-hand machinery currently in use in Vanuatu is incapable of producing high quality value-added products, such as finger-jointed panels and plywood (*pers. comm.).* Vanuatu also offers no advantage in terms of labour cost. A legal minimum rural wage of vatu 26,000 (AUD 300) /month) is set for unskilled labour in formal employment. It is for this reason that Vanuatu is no longer competitive in plantation agriculture. High labour costs will also pose a major constraint on the viability of larger scale plantation forestry that relies on hired labour.

In Vanuatu, in contrast to plantation agriculture, crops such as copra and cocoa have thrived when grown as part of traditional farming systems utilising household labour. This is because cash crops grown in this manner provide a sufficiently attractive return to household effort, even when prices and productivity are low. Economic viability of such farming systems is described in a recent study of the Vanuatu cocoa industry:

> The alternative way for ni-Vanuatu small holder to grow cocoa is to plant it as part of a food garden. A major labour cost element associated with planting stand-alone cocoa, or cocoa under coconuts, is the clearing of bush and the initial clearing of young cocoa prior to the establishment of the canopy. Thus it is not surprising that small-holder cocoa is often planted in association with a food garden – usually prior to harvesting the initial yam crop. Thus clearing and much of the initial weeding can be attributed to the food crops, as this work would have to be undertaken anyway. A typical farmer might plant 300 cocoa seedlings in a 2,000 square metre yam garden. The cocoa seedling would typically be planted in June/July prior to the harvesting of the yams in August/Sept (year 1). Cocoa plantings are typically accompanied by dry land taro, Fiji taro, island cabbage, banana, pawpaw, sugar cane, and kava as the second cash crop (year 2). In year 3 a mixed cash crop garden of cocoa and kava remains, with banana and papaya providing shade. The kava is harvested in year 4, leaving a stand-alone cocoa block. The clearing of forest and weeding for the first two years is not attributed to cocoa. This low input low output cocoa production system generates nearly 1,800 vatu per person day of effort (McGregor and Watas 2009).

The ACIAR Whitewood Project is modelling the returns to household labour from ni-Vanuatu small holders growing whitewood as part of the same traditional farming systems in which cocoa and copra grown.

5.1 An assessment of Vanuatu's competitive position with respect to timber from West Africa in the Japanese market

The major advantage of West African Obeche is that the timber is readily available in large volumes. International Trade Centre data show the fob value of Obeche lumber exports from Cameroon at USD65.6 million in 2005, down from USD 82.6 million in 2004 (2009). A small Vanuatu plantation based whitewood industry is likely to be higher cost due its relatively high wage structure, obsolete machinery and diseconomies of scale. It may have some offsetting cost advantage given its closer proximity to the market compared with Western African suppliers. Thus ways need to be found to offset these disadvantages.

5.2 Enhancing product prices to offset competitive disadvantages

For Vanuatu to have a significant whitewood export industry in the future, ways must be found to enhance product prices to offset the cost disadvantages associated with scale, isolation and a relatively high wage structure.

5.2.1 Niche markets

Perhaps the best prospect for Vanuatu in having a competitive advantage lies in being able to provide a regular supply of quality product to niche markets. The October 2009 issue of the Japanese Lumber Report presents the example of a niche timber exporter to Japan, to which a future Vanuatu whitewood processor and exporter could aspire. The German exporter Trans Sylva exports a mix of European hardwood and softwood timbers, including oak, beech, silver fir and red pine to Japan. Volume is limited, with annual export volumes of 5000-6000 m3 but quality is tightly controlled, according to Japan's high quality standards and precise shipment schedules (JLR 2009a). Japan is Trans Sylva's only Asian market, as the China market is deemed "risky" (JLR 2009a). Trans Sylva have no intention to increase volume, preferring to focus on a high quality product, specifically tailored to customer demands in Japan. Trans Sylva managing director makes annual market research trips to Japan and sources logs for customers in Japan accordingly. Trans Sylva logs are certified by Programme for the Endorsement of Forest Certification (PEFC) schemes.[7]

5.2.2 Eco-certified timber – potential market niche?

As illustrated by Trans Sylva, there are increasing prospects to enhance product prices through eco-certification.

Wood certification and green standard systems are currently immature in the Japanese market. When asked whether eco-certified products could command a higher price in the Japanese market, interviewed sources in Japan outlined that 'consumers pay on price, not on a green standard – if the price is too high, consumers will shift to substitutes for whitewood' (pers. comm.). However, it is notable that eco-certification was a part of Tran Sylva's niche marketing strategy into the Japanese market. There are significant challenges to getting eco-certification, that may not be justifiable for small operators. Outside of Japan, in countries where green building initiatives and stringent public sector procurement policies are prevalent (UK, US and to a lesser extent Australia), requirements for wood traceability and specific forms of forest certification, have placed significant obstacles in the way of tropical timbers aiming to achieve certification (ITTO 2008). For example, under the US Leadership in Energy and Environmental Design (LEED) system, only Forest Stewardship Certification (FSC) -certified wood use receives credit. Under the current US LEED System, choosing FSC-certified wood currently provides only a single point in the LEED point system, with other design initiatives, such as 'Passive Heating & Cooling' and' Water Management,' scoring higher. However, interest is high in reform to the LEED system, with growing commercial and consumer interest in Green Buildings.

In the context of the Vanuatu export timber market, the overhead costs of investing in eco-certification are high. Such an investment is probably currently not justified for a relatively small Vanuatu plantation whitewood industry targeting the Japanese market. However, a long term benefit-cost analysis of eco-certification in its various forms would be worthwhile, particularly if European and US markets are being considered for Vanuatu whitewood.

Further challenges for trade in eco-certified products in Japan include the potential threat, particularly in the current economic climate, of protectionist trade measures that favour local materials over imported, under the ambit of reducing greenhouse gas (GHG) emissions (ITTO 2009b).

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[7] http://transsylva.de/index_e.html

Recent trends in Japan's Life Cycle Assessment (LCA)[8] process have pointed to the development of protectionist interpretations of LCA data by means of 'Wood Mileage' calculators, developed by the Woodmiles Forum (COFI 2007). A Japan-based NGO, the Wood miles Forum is reputed to be supported by local industry, prefectural governments as well as the Japan Housing & Forest Products Research Centre. The Forum actively promotes the benefits of local forest products in view of reducing GHG emissions that result from importing forest products to Japan from overseas (COFI 2007).

Forest management policy reform, announced by Japan's recently elected (DPJ) government support these sentiments. Changes to forest management policies under the DPJ government include:

- a more direct focus on private operators in forest management efforts;
- an increase in Japan's reliance on domestic supply for the wood industry to 50% (instead of the current 24%); and,
- the introduction of a traceability systems to prevent illegally imported wood (ITTO 2009).

5.2.3 Carbon revenue opportunities

The returns from planting whitewood in Vanuatu could also be enhanced by capitalising on markets for carbon sequestration and ecosystem services, in a broader farm forestry model. Regulated and voluntary carbon markets are briefly reviewed in this context below.

The potential to earn revenue on carbon markets is viewed with both anticipation and speculation, as there are few examples of success in Pacific Island countries thus far.[9] The carbon market consists of regulatory and voluntary carbon mechanisms or schemes. Regulated markets are largely created by mandatory regional, national, and international carbon reduction regimes, such as the UN Kyoto Protocol and its three carbon financing mechanisms, which includes the Clean Development Mechanism (CDM).[10] The only forest-related activities available for developing countries under the CDM are Afforestation and Reforestation (A/R). A/R projects are often contentious, due to the difficulty of developing solid methodologies for calculating, monitoring and verifying emission reductions accredited to projects. In the Pacific region, two projects have been registered under the CDM thus far, neither of which are forestry-related.[11] A voluntary carbon market functions outside of the regulated markets, enabling companies and individuals to purchase carbon offsets on a voluntary basis.

Voluntary carbon mechanisms are not subject to the same level of oversight, management, and regulation as the CDM and other mechanisms under the Kyoto Protocol. In the voluntary market, project developers are more flexible to implement projects that might otherwise not be viable. The complexities and long lead times evident in the existing CDM project registration process, have seen significant attention recast to voluntary carbon markets (Carbon Positive 2009).

Discussions with carbon market specialists articulate that in principle, new, permanent whitewood plantations would be eligible for either regulated or voluntary carbon market

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[8] LCA is a technique to assess environmental aspects and potential impacts associated with a product, process, or service, over the lifetime of its use or application.

[10] The Clean Development Mechanism (CDM) is an instrument to provide incentives for greenhouse gas emissions reduction projects specifically implemented in developing countries.

[11] The two registered CDM projects from the South Pacific region are the 9.5 MW Vaturu/Wainakasou hydro-electricity generating activities in Fiji and the 55 MW Lihir Gold Mine Geothermal Plant in Papua New Guinea.

transactions as an added financial component of a forestry development business model (Sean Weaver, Carbon Partnership Ltd., pers. comm.). Permanence suggests that trees cannot be harvested, but permanence can also refer to 'carbon storage,' as per the example of Reforest the Tropics Inc., (RTT), an applied research organisation that has developed a range of farm forestry models that include verifiable carbon sequestration. The RTT agro-forestry model, aims to combine fast growth, potential income, long-term carbon storage, and ancillary environmental benefits, through stratified mixtures of planted trees.[12] Planting trials currently being conducted, will determine the optimal spacing and thinning regimes, for the particular trees that will be harvested. RTT has established and presently manages 30-odd carbon-offset forests in central Costa Rica, on behalf of US-based project proponents.

With international climate change negotiations recently closing in Copenhagen, uncertainty around the outcome means both the CDM and voluntary carbon markets remain under cautious consideration by forest project developers producing carbon offsets. However, interest in Vanuatu has remained with a proposed reforestation scheme for 20,000 acres on Malekula recently receiving significant media attention in the region. EC02 Forests, an Australian-run company registered in the United States has embarked on propagation of *Paulownia* spp. in Queensland, that is projected to see an estimated 3.3 million trees planted over the next 7 years on Malekula under the company's Global Forestry Plan[13].

According to company forecasts, the Vanuatu project is projected to absorb over 7 million tons of carbon dioxide from the atmosphere, generating 7 million saleable carbon credits for ECO2 Forests every 7 years. In this time frame, it is also estimated that the project will also produce "600 million board feet of sustainable rough sawn lumber delivering a per acre revenue estimate of US$112,520 in each 7-year harvest cycle" under its Global Forestry Plan.[14] Under ECO2's Global Forestry Plan, only sub-species from the *Paulownia* family have been specified globally, irrespective of site conditions or cultural context. This generic approach leaves little room for local site assessment and community consultation, and in the context of Vanuatu, *Paulowina* spp. are not endemic and have not been grown locally as a commercial timber species.

This has resulted in the ECO2 scheme being treated with some scepticism in the local Vanuatu media, with one report questioning whether seedlings had been left over from projects elsewhere…like 'South East Queensland, where previous *Paulowina* plantings have all failed' (Skane 2009). Another prospective project developer showing interest in Vanuatu is the Brasillian- managed Green Giant Venture Fund for what appears to be a similar, if not identical, 20 ha site on Malekula.[15] It is unclear what tree species is being planted under this model, but as per the ECO2 Malekula example, timber will be harvested in 7-year cycles.

Discussions with carbon market specialists note that potential reforestation projects would benefit from being undertaken in partnership with Vanuatu's National Advisory Committee on Climate Change (NACCC). The NACCC is the governing body for the Vanuatu Carbon Credits Project (VCCP), a national program designed to build local capacity to utilise carbon markets to help reduce emissions from deforestation and forest degradation. The VCCP is currently in a funding gap but demonstration projects can now be undertaken as part of the initiative. It is unlikely that the ECO2 and Green Giant Venture Projects were conducted in partnership or consultation with the NACCC. The query has been put to both project developers and both are yet to reply.

However, in the context of whitewood, a prospective project developer, interested in engaging in carbon market transactions as an added financial component of a forestry development business model could potentially form a partnership with the NACCC. How this partnership

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[12] http://reforestthetropics.org/forests/

[13] http://money.aol.com/article/eco2-forests-on-track-to-plant-150000/781519?icid=sphere_newsaol_inpage

[14] http://www.eco2forests.com/

would work is unclear, with the NACCC Secretariat largely engaged with recent international climate change negotiations, this query has yet to be answered. While binding commitments were missing from the outputs of the negotiations, the importance of forest preservation and enhancement were indicated via the only early funding pledge to come out of the talks- USD 3.5 billion over 2010-12 to launch the global finance mechanism REDD+. Under REDD+, payments would be made to developing nations to preserve and **enhance** forests. While the emphasis of the REDD model is on forest preservation, the inclusion of 'enhancement' under the REDD+ model, seeks to include reforestation projects currently captured under the CDM.

This funding has been earmarked for building capacity to monitor forest loss and to set up the necessary institutions to establish reporting and verification systems. The funding will likely be channelled to support the existing activities of the NACCC. Given these developments, it would be worthwhile to link a prospective Whitewood agro-forestry project/project developer with the NACCC, as a complementary objective of both this ACIAR project and the Vanuatu Carbon Credit Project. Some of the principles of the Reforest the Tropics farm forestry model from Costa Rica could well apply to the Vanuatu context.

6 Major findings

- The future of the whitewood industry largely lies with selling to export markets where the timber's particular attributes can command price premiums. These premiums are not available to whitewood sold as a general construction timber on domestic markets. Without a high level of protection, whitewood cannot generally compete with New Zealand radiata pine on domestic markets.
- Good quality timber, produced in sufficient volumes, will become an increasing valuable commodity in international trade. Potential investors in the growing and processing of whitewood can draw some confidence from long-term price data. They will be investing in a commodity that has experienced a steady increase in real prices over three decades and which are expected to increase into the future. In contrast Vanuatu's major agricultural export commodities face an uncertain price future.
- If a sustainable whitewood resource can be established, a remunerative market will always be available in Japan and could be expanded.
- Between 1998-2007 Vanuatu exports of whitewood products to Japan and the Asian markets tracked between 1000-3000 m^3/annum. There have been no exports since that time, despite the products being well received in the market.
- Vanuatu Whitewood is favoured in the Japanese market because of its: light colour; low-medium density; ease of kiln drying; and, excellent in-service characteristics (low movement).
- In the context of interior application, there has been a growing trend in the Japanese market for non-structural wood products, largely driven by increasing consumer demand for use of light coloured softwoods.
- Vanuatu Whitewood is perceived in the Japanese market as an adaptable timber, particular suited to 'face and back veneer' uses. The main timber competitors in these uses are PNG basswood (*Endospermum* spp.) and African maple (*Triplochiton scleroxylon*). There are also temperate region timbers with similar physical characteristics.
- Globally the last few decades have seen timber veneers and plywood become more widely used, particularly in furniture manufacture. This trend has been largely driven by the increasing cost and difficulty in obtaining quality hardwoods.
- Japan's tropical veneer production has dropped by two thirds over the last decade, with its tropical veneer and plywood industries contracting due to declining log availability, and its stagnant economy during most of that period. However, there has been an increasing the proportion of softwoods used in plywood and veneer production.
- Japanese plywood manufacturers have begun establishing joint ventures for plywood and other panel products in producer countries where costs are more competitive. This offers a potential opportunity for a Vanuatu processor if productivity and quality can be improved.
- A number of traditional exporters of primary timber products have begun making the transition into Secondary Processed Wood Products (SPWP), including light construction and joinery. However, Vanuatu with its high formal sector wage structure, relative to productivity, currently would not have a comparative advantage based on

processing costs. For a Vanuatu industry to be competitive it will need to attract substantial capital investment into processing equipment.

- While there are opportunities for value added, in the past Vanuatu has not able to consistently cut and supply to specification (following the '**3 5 50' mm** dimensioning rule for roughsawn timber). The fundamental requirements for developing the Japanese market are 1) reliable supply, 2) cutting to specification and 3) quality control -no blue stain.

- Quality is important, but is relatively less important than the creation of a sustainable supply base for the market.

- The major advantage of African maple is that the timber is readily available in large volumes from Cameroon. A small Vanuatu plantation-based whitewood industry is likely to be higher cost due its relatively high wage structure, obsolete machinery and diseconomies of scale.

- For Vanuatu to have a significant whitewood export industry in the future, ways must be found to enhance product prices to offset the cost disadvantages associated with scale, isolation and a relatively high wage structure.

- Perhaps the best prospect for Vanuatu to have a competitive advantage lie in being able to provide a regular supply of quality product to niche markets, along the lines of the German importer to Japan, Trans Sylva). Eco-certified timber represents another opportunity.

- Returns from white wood plantations could potentially be enhanced by capitalising on markets for carbon sequestration and ecosystem services, in a broader farm forestry model.

- There is a need to investigate the potential to link between the ACIAR White Wood Project to the work of the Vanuatu Carbon Credits Project (VCCP), with the aim of developing a farm forestry model, such as that of the Costa Rica Reforest the Tropics Inc, under the VCCP demonstration projects phase.

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Silviculture of whitewood (Endospermum medullosum) in Vanuatu

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2/21/2012

Southern Cross
UNIVERSITY
A new way to think

Summary

The native stands of timber on most of the Pacific islands have been under considerable pressure from timber harvesting and subsequent clearing for agriculture and other local development. As a result many areas of the Asia- Pacific are experiencing shortages of wood to supply export markets and domestic needs. The current timber harvest for the entire country of Vanuatu is less than 1000 m3 per year. This is equivalent to the amount of whitewood that could be produced on one 5 ha block at the Shark Bay site in just 15 years. Whitewood is a local species that has been highly sought after for high value uses, such as panelling and furniture. Vanuatu's whitewood resource in native forest is virtually exhausted, "its presence in more accessible areas of native forest is down to a residual of few young trees and a few old poorly formed and senescent trees" (Viji et al., 2005).

In the short to medium term, the timber reserves of Vanuatu will require substantial assistance from a plantation programme to ensure continuity of wood supply for both the domestic and export markets. Given that there are considerable reserves of cleared land (both degraded farmland and underutilised pasture land) available, the country has significant potential to increase plantation area as a supplement to the native stands. This Manual aims to provide a step by step guide on how to develop successful timber plantations and mixed species agroforestry systems using whitewood in Vanuatu for a range of purposes.

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The ACAIR Whitewood Project (has also benefited from the support and dedication of many people and organisations. We gratefully acknowledge the landholders who have provided access to sites, where we have been able to establish trials and to measure their woodlots, particularly Victor Andre at Belaru, Chief Malakai at Sara, James and Edwin at Jubilee Farm and Kelsai at Lorum. To the Vanuatu Department of Forestry (VDoF), thanks to Tate Hanington, Ioan Viji, Joseph Tungon, Dick Tomker, Leimon Kalomor, Sammy Kaku, Allan, Wendy Tomker, James, Rene, David, Olister, Sero and Mackenzie. To the landholders and participants of the workshops and training, thank you for your support, and good luck with the whitewood plantings. We acknowledge the support of Melcoffee Sawmils for transporting and sawing up whitewood grown in young plantations to determine wood quality. Thanks to the Australian Youth Ambassadors Kate Covery and Bronnie Grieve, for a great contribution and commitment to delivering the Project outcomes. To the management, staff and student at VAC, particularly Rodney Aru and Peter, we thank you for your contribution to the trials and participation in demonstration activities. A very special thank you to Mesek Sethy for his dedication, commitment and hard work: this project has been dependant on the experience and enthusiasm of Mesek to deliver a successful outcome.

Introduction
Forests in Vanuatu have been central to economic and social prosperity; timber exports have provided a valuable export industry in the past, and forests continue to provide essential environmental services that are more difficult to place a value on. Development of a plantation industry will be an important focus that will also assist in Vanuatu developing a sustainable forestry industry and moving away from reliance on existing natural forests. Plantations using local timber species, such as whitewood, can produce large volumes of high quality timber from relatively small areas of degraded and weed infested land. To establish productive plantations growers need to have information about establishing and managing trees to provide a range of goods and services. The management of forests is referred to as silviculture. Silviculture of planted forests will be examined in this manual and is primarily applied to the production of whitewood. However, other key species have been included for use in mixed species agroforestry systems. As pointed out by the Director of Forests of Vanuatu (Hanington 2011), "*the planted forests of Vanuatu provide a comprehensive range of goods and services that are important for environmental, social and economic reasons:*

- *Clean air and water;*
- *Food and medicine;*
- *Soil fertility and stability;*
- *Building materials and fuel wood;*
- *Cultural and spiritual significance;*
- *Create jobs and generate income;*
- *Potential to mitigate greenhouse gas pollution and store carbon;*
- *Forest protects terrestrial biodiversity."*

Current Forest Situation in Vanuatu
In the period from early 1980's to mid-1990 whitewood logging from natural forests has been an important economic activity in Vanuatu. Most of this timber was exported to Japan and other Asian countries for high value panelling and furniture production. Following this extensive logging, particularly on the island of Espiritu Santo, Vanuatu's whitewood resource in native forest has been largely exhausted and there have been virtually no exports in recent years. The primary forests of Vanuatu have been depleted, and what remains is mainly found above 500 m, are secondary, containing gardens throughout which are rich in species of practical use (Walter and Lebot 2007).

Vanuatu is trying to balance a need for development with policies that ensure conservation of its environment. To achieve this end, the Vanuatu Government has stated an intention to increase the plantation estate seven-fold over the period to 2025 to reduce the pressure on remaining natural forests and to develop domestic and export market opportunities. There are very suitable areas of productive and under-utilised land in Vanuatu that have the capacity to provide this timber production policy goal (Figure 2). One of the major challenges is to work out how best to convert weed infested sites into productive plantations that have a high timber value (Figure 2).

Figure 2 Degraded land in Santo (left) that can be converted to productive plantations (right) ready for harvest in less than 15 years.

The development of significant areas of productive plantation will require that landholders, extension officers and policy makers have the latest information to provide a good understanding of the land available and the best methods of growing trees and processing timber given the scale of the resource. This silviculture manual has been developed from research conducted by ACIAR to inform growers of the range of issues that will be critical to developing a productive plantation estate including:

- Growth rates of planted whitewood across a range of sites- Detailed site survey of existing whitewood plantings, both timber plantations and agroforestry systems to determine growth and selection of other suitable plantations species;
- Establishment, site preparation and weed control experiments, to assist growers select appropriate systems to grow whitewood for a range of products;
- Establishment of thinning trials in existing plantings;
- Examination of spacing effects on growth and canopy characteristics in new and existing plantings,
- Assessment of existing mixed plantations of whitewood and establishment of whitewood interspersed with other species such as *Terminalia catappa* and *Flueggea flexuosa* for food value, high value hardwood and short-term yields.
- Assessment of wood properties from a range of sites, ages spacing and thinning trials, to help identify potential wood products.
- To determine the use and markets for wood from plantations, analysis of wood characteristics in whitewood from the varying regimes, to assist in the development of basic productivity and yield models, and financial analyses

Economic and environmental benefits of plantations

There is an existing domestic and export market for whitewood in Vanuatu, and Vanuatu has led the development of whitewood as a plantation species. Despite this effort, the supply of whitewood being exported has dropped dramatically. In 2003 timber exports of whitewood represented 14.5% of total exports, by 2008 timbers share of total export earnings had fallen to 2.5% (Kiko 2009). This manual seeks to address this issue of timber supply by helping to encourage the development of productive plantations and to maximise the growth of existing whitewood estate. Good silviculture will help to foster the development of a larger area planted in the local species, this will in turn provide both economic (Figure 3) and environmental benefits for Vanuatu.

There has been a very successful effort to develop good methods to select and grow whitewood seedling for timber. A significant amount of genetic improvement and propagation research has already been carried out under the SPRIG Phase 1 and Phase 2 projects. At present, there is a source of selected seed from seed orchards and there is a wide range of small whitewood planting from which to study the growth and wood properties of this fast growing species.

Figure 3 Sawn wood from rural woodlots being transported for sale.

Current progress on developing a whitewood plantation industry

One strategy adopted by the Vanuatu Department of Forestry (VDoF) has been a plantation tree improvement programme for Vanuatu whitewood, aimed at increasing the economic value of the industry. A key objective of the strategy is the progressive provision of more productive germplasm to growers while conserving genetic resources both in- and ex- situ. This programme is focussed on enhancing grower uptake, increasing planting rates and conserving genetic resources. This work started during AusAIDs South Pacific Regional Initiative on Forest Genetic Resources Project (SPRIG) (Thomson 2003) with the establishment in December 1998- January 1999 of two (one major and one minor) provenance/family trials of whitewood near Shark Bay (IFP) on the east coast of Espiritu Santo island. Statistically significant and heritable provenance and family within provenance variation in growth (height, diameter and volume) traits in the major trial was reported by Viji (2005) and Vutilolo et al. (2008) when the trial was 4 years-of-age. In 2011 a study of wood quality was conducted at the same site by the Whitewood genetics project to determine the range of wood density across the best performing families (Figure 4).

Figure 4 Taking wood core samples from IFP seed orchard to compare wood density of different whitewood families.

Challenges facing plantation growers of all kinds

Vanuatu faces similar challenges as many other nations establishing a new plantation industry. Often there are significant challenges regarding the selection of plantation species, finding appropriate sites, having well developed management systems for productive plantations and finally developing and marketing products.

In Vanuatu, there have been some encouraging developments. There are currently private commercial scale plantations and an associated processing infrastructure that provide a model for plantation developments. Community-based plantings of whitewood have also expanded during the past decade. However, there is a need to address the lack of infrastructure and product development particularly for smaller trees, and growers need to be aware that there is some work that needs to be done to find a market for smaller logs in Vanuatu.

As populations grow, so do the demands on forests to provide timber or to provide land for agriculture. The government of Vanuatu has stated that a seven-fold increase in the plantation estate is a priority over the next 18 years and to facilitate a whitewood plantation industry in Vanuatu. Like all new plantation species, the single most important technical impediment to realising this economic opportunity is the absence of silvicultural prescriptions that will optimise productivity and product value.

Aims and Objectives

The aim of this Manual is to describe a range of comprehensive silvicultural prescriptions for industrial and community-based plantation forestry with whitewood (*Endospermum medullosum*) in Vanuatu. This Manual will focus on the design of plantations, site preparation, spacing, thinning, pruning and maintenance and weed control. Whitewood producers will also need to be aware of the market for their wood products, so some discussion of the important aspects of the market will also be presented. The scope of this Manual is to outline prescriptions that involve both pure stands of whitewood and mixtures with other tree species and traditional root crops.

The goals of the ACIAR Whitewood project are to:

- identify site selection criteria, and characterise site availability, with focus on Espiritu Santo island,
- define appropriate establishment silviculture prescriptions and
- define stand management systems that optimise economic returns (through manipulation of both productivity and wood quality). The output of the project will be comprehensive silvicultural prescriptions for whitewood as a plantation species, and a thorough economic analysis of the costs and benefits of plantation establishment under different regimes, documented in a species manual.

Whitewood- Description and Ecology

Endospermum medullosum L.S. Smith (family Euphorbiaceae), has many common names including basswood in Papua New Guinea and whitewood in Vanuatu (Thomson 2001, 2006). It is typically a tall forest tree to 45 m in height, often with buttresses and large surface roots, in natural forests this species is usually in the 50 cm to 100 cm diameter range. It is predominantly a pioneer species of lowland to mid-elevation sites in humid tropical climates of high rainfall (2,500-4,500 mm/year) and short to no dry season. Boles (tree stem) are typically long and straight (Figure 5), outer bark is light brownish-grey often appearing whitish from a distance, the peltate or cordate, darkish green leaves are large (up to 30 cm long and up to 25 cm across) (Doran et al. In Press). The canopy structure of the tree is marked by a flat-topped crowns, and large spreading branches borne in tiers, or whorls.

Figure 5 Young plantation grown whitewood tree with the characteristic straight stem (bole).

Whitewood has been identified as a timber species with strong forestry plantation and agro-forestry potential in Vanuatu and the South Pacific region (Thomson 2006). Good timber properties, together with rapid growth and high cyclonic resistance, make whitewood a particularly suitable species for forestry plantations in Vanuatu (Vutilolo et al. 2005).

Natural Distribution

Whitewood (E. medullosum) occurs naturally in Indonesia (West Papua), Papua New Guinea, Solomon Islands including the Santa Cruz Islands and in Vanuatu. In Vanuatu, E. medullosum occurs naturally on more than a dozen islands from Erromango (c.19°S latitude) in the south of the archipelago to the Banks Group (c.14°S) of islands in the north (Vutilolo et al. 2008).

Fruiting

The species is dioecious, meaning that there are both male and female plants. The seed is only produced by female plants. The flowers are insect pollinated, and can be produced at varying times of the year depending on temperature and rainfall conditions. The fruits form fleshy drupes (Figure 6) that are distributed by birds and flying foxes (Thompson 2005).

Figure 6 Leaves and some fruits forming in bunch along the branches. (Source T.Page)

Principles of plantation growth

To grow healthy and productive plantation trees, the grower need to make some very important decisions before starting to plant. The first decision is to identify the objectives of the planting, once the objectives are clear then the grower will need to select the appropriate species. Plantation design will also need to take consideration of the site to ensure the trees have adequate light, water and nutrients to grow rapidly. In this chapter the principles of how trees grow will form the basis for plantation silviculture described in the rest of the manual. The basic principles of tree growth are explained to help growers understand the needs of the trees and the implications for management.

Tree requirements and characteristics

Trees use basic elements of energy from sunlight, carbon dioxide from the atmosphere, nutrients from the soil and water to grow. The growth of individual trees will be determined by the access to these basic elements. As trees grow larger they need more of these basic elements to survive and continue growing. If any one of these basic elements is limiting then tree grow will be restricted. In tropical forests light is often a key limiting factor for the development of trees, and so competition for light is a key consideration for plantation growers (Figure 7).

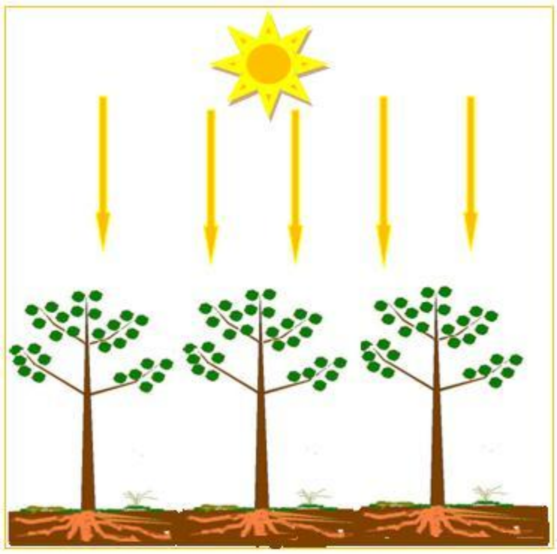

Figure 7 Trees use light from the sun and nutrients from the soil to grow.

Nutrients are chemical elements that are essential to plant growth; they are required for all of the processes that drive tree growth. Most of these nutrients are found in the soil and are taken up into the plant trough fine roots together with water. The nutrients and water are then transported around the plant though the roots and outer layers of the stem to the leaves. The process of photosynthesis, that creates food which enables growth, is driven by sunlight and access to a balance of key nutrients Therefore, soil assessments are an important part of determining the best species and management for a site (Figure 8).

Figure 8 Sites and their soil profiles conducted by the ACIAR Whitewood project staff (photos by John Grant)

Trees grow up and also grow out.

It is useful to think of trees growing up from the top, and out at the base as well. A tree will increase its height to make sure that it can compete for light. The diameter of the stem will increase as the tree grows to support the branches, in this way trees will also grow out as well. The height growth of trees is not very strongly affected by the spacing of trees in a plantation (West 2006). However, the diameter growth of a tree (growing out) is very strongly determined by the space available to a tree. When trees have plenty of space they will often grow large branches and the stem diameter will grow rapidly. However, when trees are crowded in they will often grow tall and very skinny, which is a major concern for timber production systems. The production of valuable wood is highly dependent on plantation growers ensuring trees have adequate space to grow out, not just up.

If a whitewood tree is given good access to light, water and nutrients then in the first few years the trees can grow up to 5cm a year in diameter, so a tree can have a diameter of 25cm five years after planting. As competition between trees increases, particularly in closely spaced plantings, the diameter growth of individual trees will slow down dramatically and in some cases growth in diameter can stop if competition between trees is not reduced.

The diagram below (Figure 9) tries to show how given the same amount of space the number of trees planted will be a strong determinant of the growth in the diameter and the size of the branches. Given plenty of space trees will grow out as well as up, in close spacing individual trees cannot grow out. Often plantations will be closely spaced at first then trees can be cut to provide more space later (Figure 10)

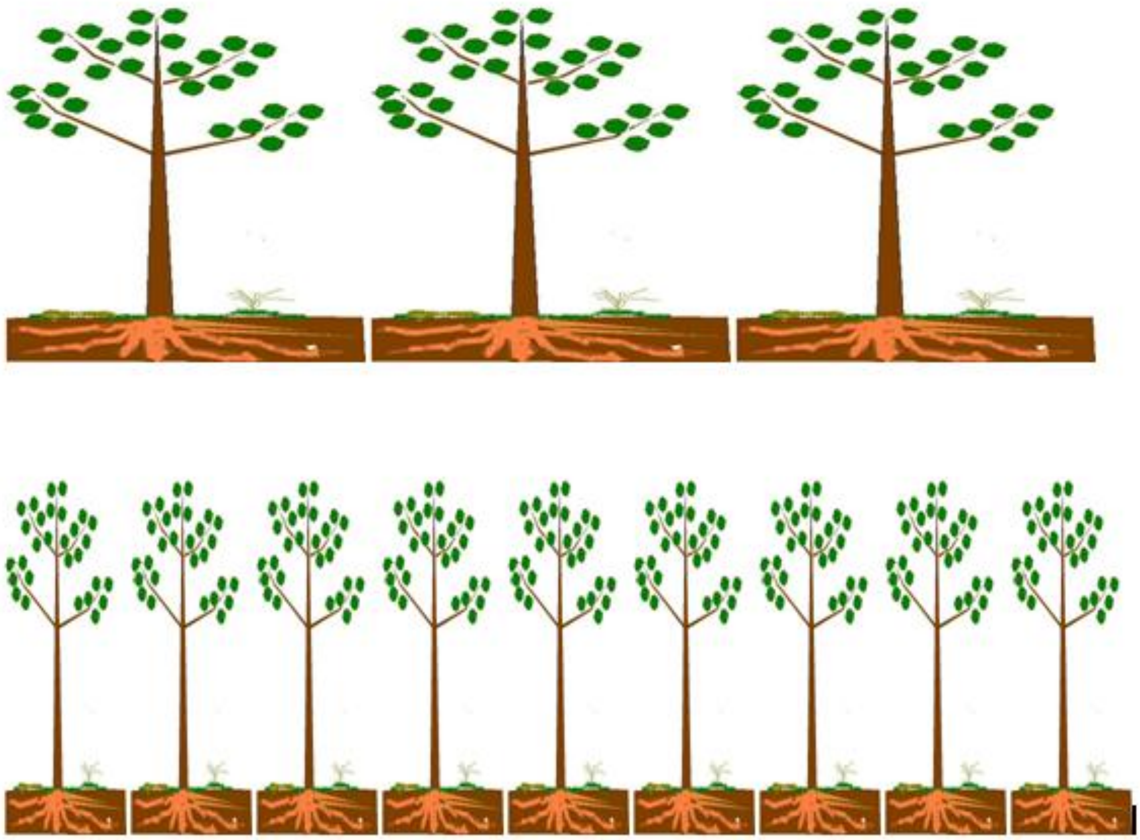

Figure 9 Trees will grow according to the amount of space and resources they have available. Trees with lots of space will grow wide (Top row), whereas trees that have little space will grow tall and thin (bottom row).

Figure 10 Close spaced whitewood at 3 years old where competition will soon reduce the diameter growth of trees, so they will continue to grow up, but not out.

Nursery and seedling production

Successful plantations are dependent on access to good seedling stock grown from good quality parent trees. Forest growers can decide to obtain seedlings for their plantation from nurseries, or with a bit of effort they can produce good quality seedlings within a few months themselves. One of the major benefits of producing your own seedlings is cost savings, but growers need to make sure that care is taken over the quality of the seed and the conditions under which the trees are produced. To produce a large number of seedlings growers may need to build some very basic structures to assist in the production of healthy seedlings (Figure 11). The main structures required are seed beds and some areas that provide some shade and shelter to ensure the rapid growth and development of the young trees.

Figure 11 Whitewood and namamou grown in the DoF nursery in Santo.

Plant Propagation- Seed collection and storage

Seed collection

The seed of whitewood is contained in fleshy drupe that is held on bunches on the female trees. The seeds are difficult to find on the ground and are often eaten when ripe. To collect seed it is often best to break off the branches with bunches of seed while still on the tree, using a rope thrown over the branch or an extended pruning saw if the branches are lower.

It is important to make sure that the trees that are used as seed trees have good qualities, a straight trunk (bole), small branches and vigorous crown. It takes good parent trees to make good quality seedlings. In Vanuatu there has been a good effort to put in to develop seed orchards of good quality trees that can be used to ensure goo quality seeds (contact Department of Forestry Staff about information on seed availability).

Seed storage

Whitewood seed is best used fresh, and can be stored for a short period in a cool dry place. The flesh of the fruit needs to be removed and the black seed if seed is not sown immediately. Seed viability can be tested by placing the seed in water as soon as possible after picking the seed, with the floating being discarded (Thompson 2005).

Containers for seedlings

The collected seed is most often placed in seed raising beds (Figure 12) rather than planted directly into pots. The small seedlings are gently removed from the free draining seed raising mix, usually garden soil with at least 50% river sand, and then placed into pots or bags to grow on before planting in the field.

Figure 12 Seedling sprouting in a seedbed using well draining soil and sand.

A nursery trial of seedling containers was conducted by ACAIR staff on Santo, using both bags (1 litre capacitiy) and root training forestry pots (50mm tubes), to see if seedling root growth of whitewood is affected by the type of container. In previous planting of whitewood on Santo, bags have been used with success, but roots can tend to grow in ways that may create problems later. The use of root trainer pots is a relatively new approach of ensuring root development is well is well formed compared with 1 litre bags. The aim of this experiment is to test the two seedling container systems to see if seedling height growth and root development are affected under three fertiliser regimes.

The root trainer pots (50mm) trailed at the Melcoffee Nursery tended to rely on a very rapid seeling production and planting cycle. The whitewood seedlings quickly out grew the pots if trees were not planted out rapidly. If trees were held in the nursery too long the trees in the 50mm pots would quickly become root bound and the lower volume of the potting mix required very regular watering. The smaller containers may not adequately allow for seedling root development in the nursery (Figure 13). The (1 or 2 litre) bags have a larger capacity to hold potting mix than the root trainers, which may allow trees to be held in the nursery longer and to be planted out with better root development. However, the bags can be difficult to water if bag is not filled to the top, (the plastic collapses over the soil and the water tends to run off).

Figure 13 Plastic bags (left) filled with garden soil ready for the transplanting of seedlings from seed raising beds. Small seedlings (right) in 50mm pots grown under shade to reduce stress in the dry times of the year.

Larger rigid root trainer pots (75-100mm) pots are the most suitable containers, allowing for the rapid growth of the whitewood seedlings. The larger containers give sufficient volume of potting mix and allow for more water to support root growth in hot conditions. However, these larger root training pots can be expensive and are difficult to source in Vanuatu.

Site selection

Whitewood is naturally found on humid lowland sites with high rainfall (2500-4000 mm/yr) and grows on a wide range of soils (Thompson 2005). The sites where plantation timber is often grown are in areas on the margins of agricultural areas, on slopes and land around gardens. Trees do not tend to require the same intensive management as agriculture, so trees are often planted in areas that may be less accessible and on land that is not required for agricultural production on a regular basis.

In Santo a map of highly suitable sites has been produced to help growers select sites. The sites are located mainly along the east coast and central areas of the island. The 52,000 hectares of highly suitable areas do not include those areas currently used for agriculture, including coconuts (Figure 14).

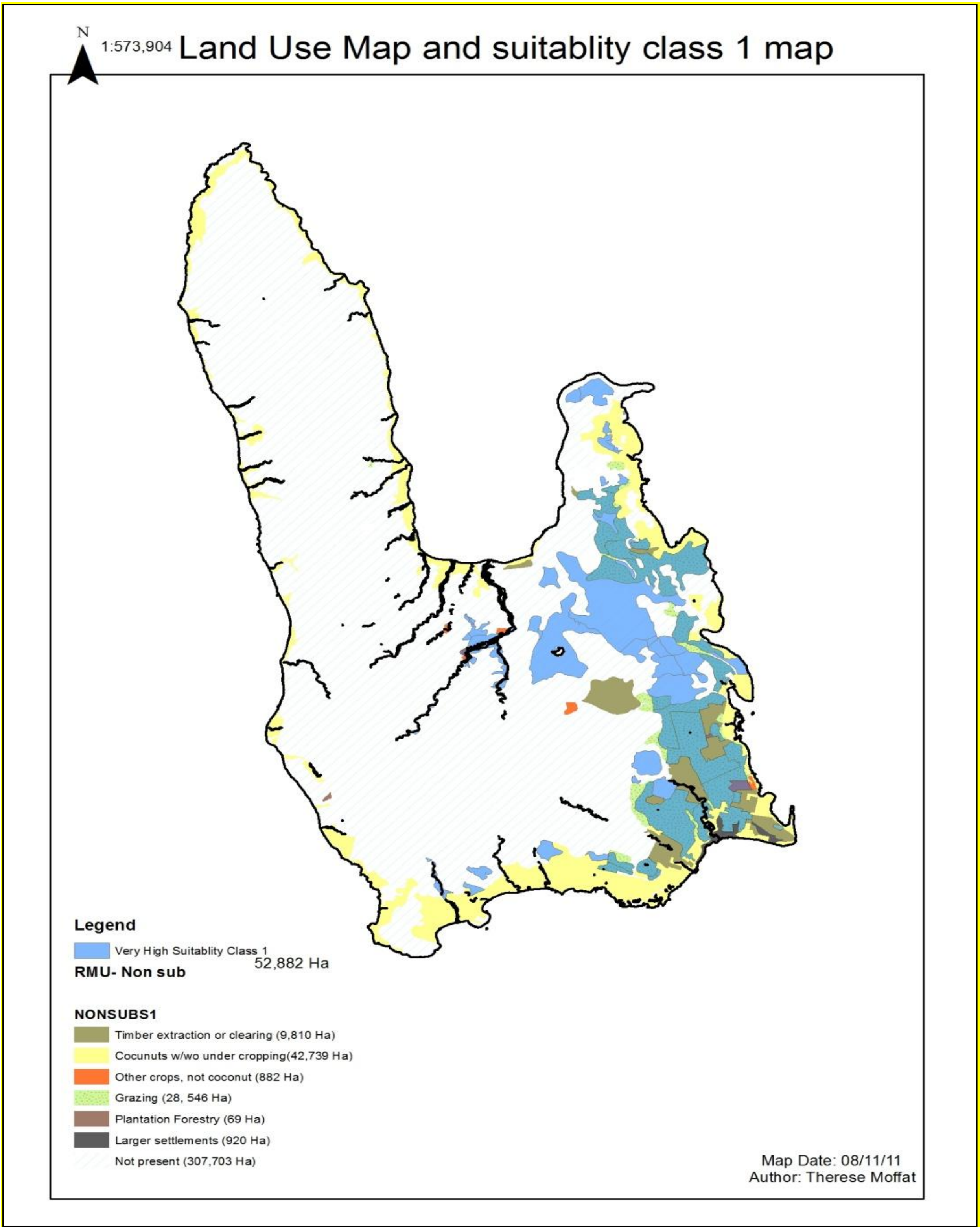

Figure 14 Land use and site suitability of whitewood on Santo

Soil conditions

As a part of the ACIAR Whitewood Project, soils have been assessed by a specialist soil scientist to help describe the range of conditions under which whitewood is currently grown and to relate soil to tree growth. The soils of Santo tend to be suitable in general for whitewood production, being relatively fertile and well draining (Figure 15). The soils have high organic matter and good nutrient status, but some additional nitrogen, zinc or boron may be required in some conditions (Table 1). Sign of nutrient stress will show as yellowing of the leaves or brown spots on the leaf surface.

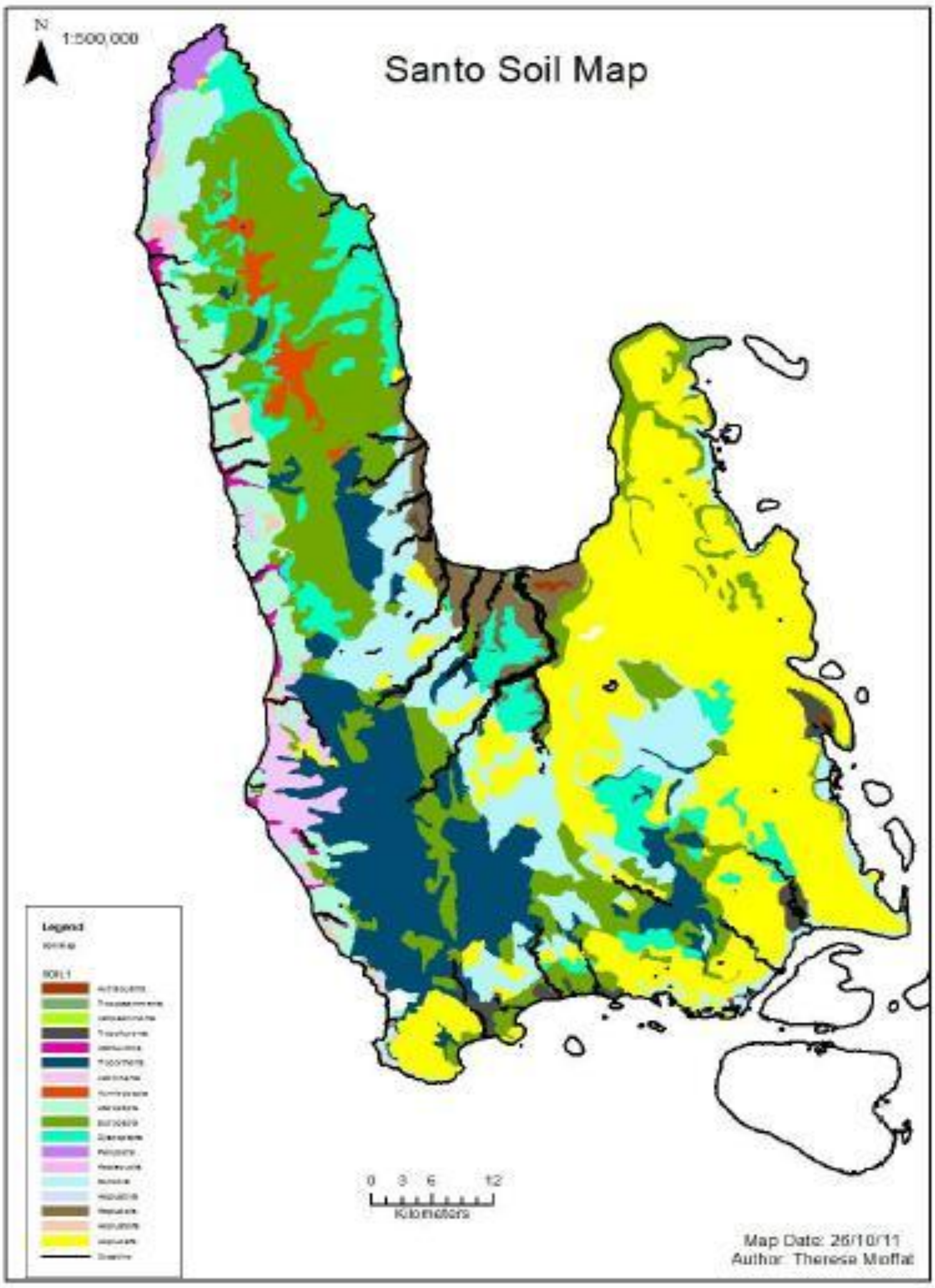

Figure 15 Soils of Santo, with the soils of the yellow classification, those currently planted with whitewood, being described in Table 1 (Source information VANRIS from Grant et al 2011).

Table 1 Soil nutrient staus of topsoil and subsoil across Santo.

	Topsoil	Subsoil
Available Phosphorus	Low	Low
Organic matter	High (9%)	High (6%)
Extractable Ca, Mg, K	Adequate	Adequate
Total Nitrogen	Adequate (0.6%)	Adequate (0.4%)
C/N Ratio	Marginal (9)	Marginal (9)
Zinc	Low?	Low?
Boron	Low?	Low?

Site and Species matching

One of the major challenges for forest growers is to match the right species with conditions at a site. The decision about which species have the ability to grow and thrive on the site is generally based on soils, climate and aspect. In Vanuatu, where soils are generally fairly fertile and rainfall is reliable a wide range of species may be possible. In such cases where there may be a wide range of species possible, the species selection may be then be primarily influenced by the exposure to risks, such as cyclones, pests and brown rot. Whitewood has a high tolerance to brown butt rot fungus (*Phellinus noxious*) (Ross Wylie per. com). This disease, which spreads through root grafting, is considered a major risk factor for timber plantations of nearly all other tree species in Vanuatu (and Fiji). The high tolerance of whitewood to brown butt rot reduces the risk of disease problems with second and subsequent generations of whitewood.

Where growers are not looking to sell their products to processors, but to supply their own timber needs, selection of appropriate species will be driven by the building materials that are needed, or fodder or fencing requirements. Tropical hardwoods such as mahogany and teak take longer to grow to harvestable size and are more prone to damage from pests, cyclones and diseases such as root rot. However, mahogany can be used without treatment so local utilisation is less problematic. Whitewood logs have a high demand by processors and can be grown relatively quickly, over 15-20 years, but growers need to be able to get their wood to a treatment plant quickly to make sure that the borers do not damage the wood.

So the selection of species needs to be made in the context of what can grow on the site, what can be used locally or can be readily sold to processors and what is a low risk of failure due to damage or disease. If looking to plant mixed species woodlots then the growth rates and the stem form of the species may be an important factor to consider.

The wood products that are desired from the plantation may also drive the decisions about species selection. The presence of an existing market for wood is a very important factor for species selection; the presence of a log buyer and the price paid for logs locally will often influence the decision over what are a grower's preferred species. If a woodlot grower is interested in selling logs to a processor, rather than using the timber locally, there will need to be sufficient logs of a high quality to ensure that the costs of harvest and transport are recovered.

Initial spacing in timber plantations and agroforestry systems

Initial Spacing

One of the most important concepts that all producers of high value sawn wood need to consider is the spacing of trees and how that may need to change over time. The space available to individual trees will be a critical factor in determining the growth rate as the trees mature. The stand density or stocking is the number of trees per hectare, and this will range from very close spacing of 1100 stems per hectare where rows are 3 metres apart and around 3 metres between trees. A wide spacing may be 10 metres by 10 metres where there are only 100 trees per hectare

Figure 16 Young whitewood at quite close spacing (833 trees per hectare) with peanuts planted underneath at Victor's Trial Belaru, 2008. (Trees planted at 3m between trees and 4 m between rows).

The stocking rates will be dependent on the objectives of the plantation grower, the conditions at the site and the age of the trees. At the very beginning of the plantation process the grower will need to develop clear objectives that will influence the number of trees planted and the arrangement of the trees across the site. If the grower wants to incorporate trees into a crop production system then the space between tree rows may be kept wide to allow the crops plenty of light and water. If the grower is focussed on producing large sawlogs, then trees may need to be quite densely planted initially and then a large number of (70-80%) trees removed over time.

Row orientation and tree spacing may reflect the needs of the grower and the role the trees play in the landscape. In Figure 17, some common row spacing are shown that reflect quite different forestry situations in the same area. In a sawlog regime, high stocking rates are common, at 3m between tree rows, there will be eleven rows in the 30m wide strip of plantation tree rows. If we assume in the top tier of the drawing (Figure 17), that the trees are spaced at 3m within the rows as well, therefore, we have a 3m x 3m spacing. This represents a high density timber plantation, with a total stocking of approximately 1,100 trees per hectare. In the middle tier of the drawing, the tree rows are 6 metres apart (6x3m spacing), as in a moderate density plantation or agroforestry system, where crops may be grown for the first 3-5 years, with a total stocking of approximately 533 trees per hectare. In the bottom tier of the drawing, the tree rows are 10 metres apart (10x3m spacing), as in a lows density agroforestry system, where crops can be grown in conjunction with timber trees, with a total stocking of approximately 300 trees per hectare.

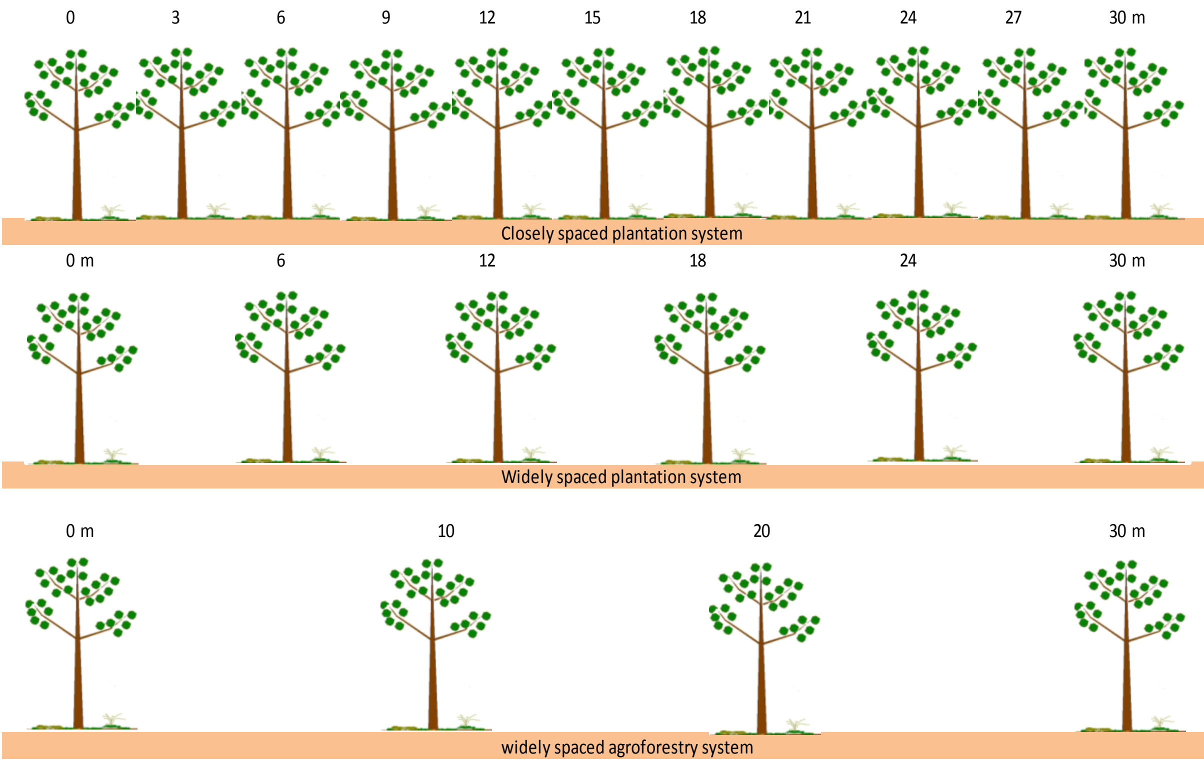

Figure 17 Spacing of trees in a sawlog timber plantation (top- 3m between tree rows), a high density agroforestry system (middle- 6m between tree rows) and a low density agroforestry system (bottom- 10 metres between tree rows).

Common spacing for specific forestry planting systems

The close spacing of trees in a timber plantation (above 500 trees per hectare) provides some advantages to growers; firstly the higher number of trees creates more shade that reduces weed control. In Figure 19 the understorey is very clear and free of weeds that may compete with trees, and in particular it is too dark for merrimia under these types of plantations. The high number of trees also helps to keep trees growing straight and may help to reduce the number of trees with bends in the stem. The competition between trees in a closely spaced plantation will also often reduce the size of lower branches that may cause knots in the most valuable part of the log. If we look at the trees in the widely spaced plantations, those trees tend to have large lower branches and a higher proportion of trees that have major bends in the lower stem. The following section provides some examples of silvicultural systems that may be developed for particular circumstances.

High density sawlog plantations

Closely spaced, high density plantations are often established to allow growers to select the most vigorous and straight trees to grow on to a high quality sawlogs (Figure 18 and 19). Often a grower need to start off with at least 800 trees per hectare to end up with 250-300 high quality trees at harvest in 15 to 20 years. This style of planting will require that the grower do thinning at various stages along the way of the plantation to ensure that the growth of the most valuable trees is maintained. If thinning is not undertaken in closely spaced planting the value of the timber can be reduced significantly. The figure (Figure 18) below provides a plan view, looking from above, at the spacing of trees in relation to each other within tree rows. In this situation the tree rows are 4 metres apart and the trees are 3m apart within the rows.

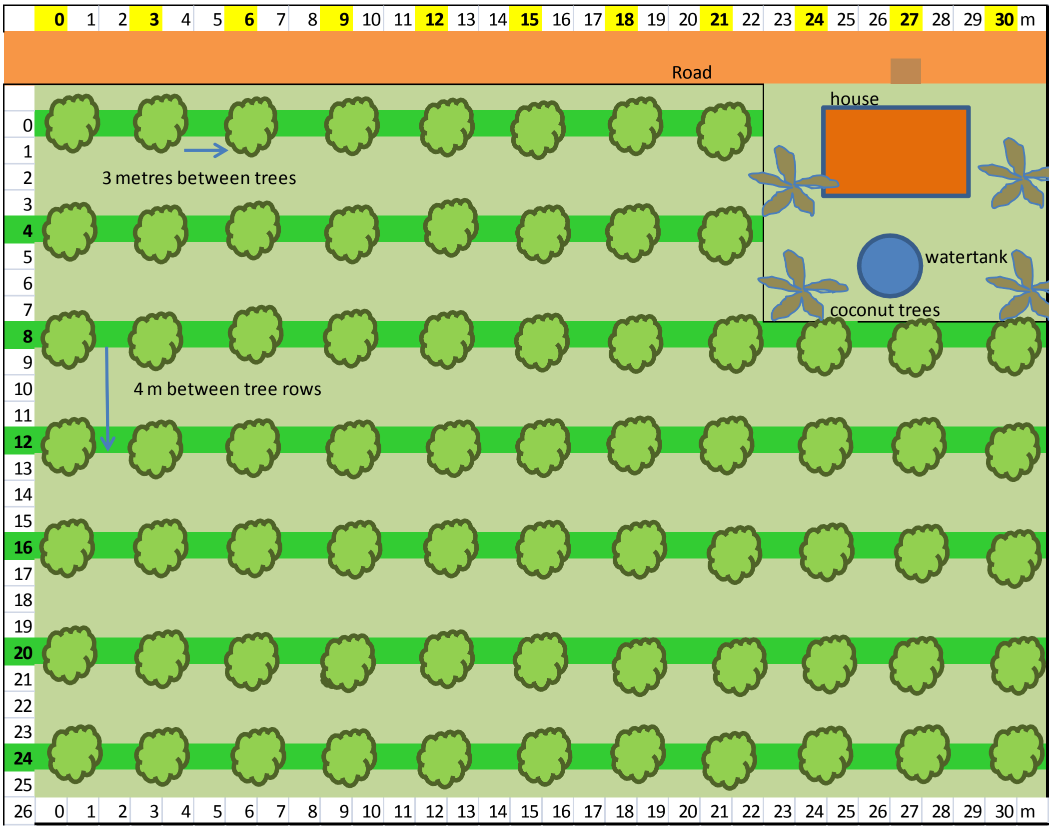

Figure 18 A plan view of a closely spaced whitewood planting (4m between rows and 3m between trees- 833 trees per hectare) close on a typical small rural landholding

Figure 19 Very close spacing at approximately 833 trees per hectare at three years old at Belaru with very little weed growing under the trees (plantation spaced at 3m between trees and 4m between rows).

Moderate density timber plantations

The most common spacing of whitewood plantings in Vanuatu is in the moderately close spacing in range of 400 to 500 trees per hectare. Often these trees are planted at spacing of 5 to 8 metres between rows. In the moderate spaced planting weeds continue to persist in the plantation longer so weed control needs to be conducted for a longer period, often up to 4 years (see weed growth in Figure 21). The moderate stocking provides growers with a broad range of options where trees can be spaced in a more square formation (5m x 5m) a slightly rectangular arrangement (6m x 4m as in figure 20).

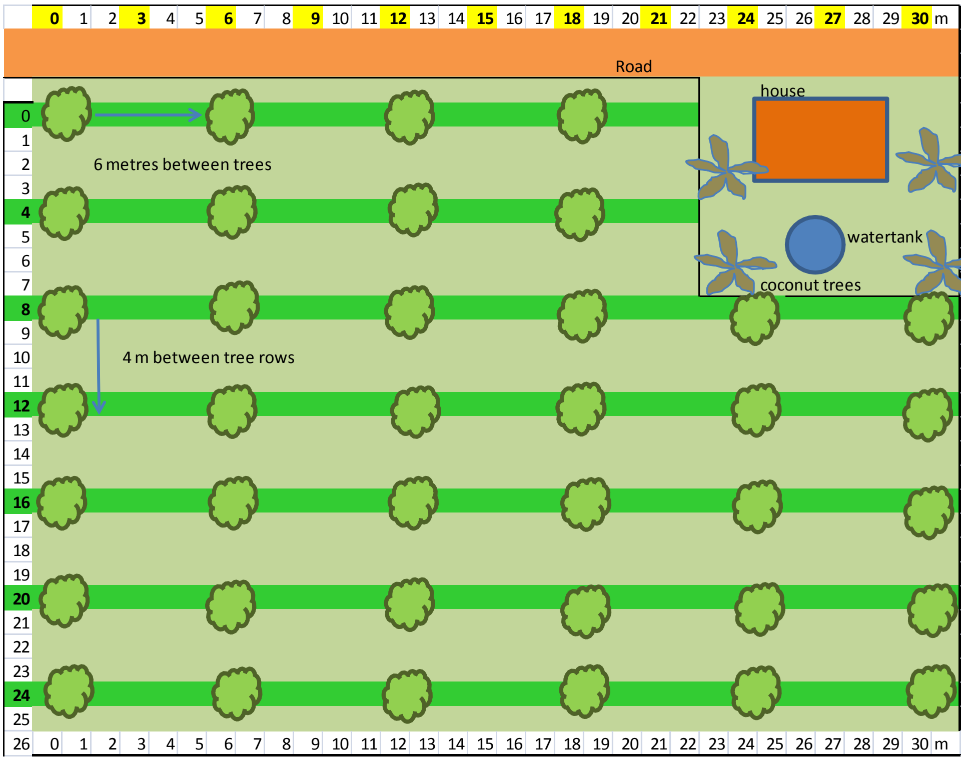

Figure 20 A plan view of a moderately spaced whitewood planting (4m between rows and 6m between trees- 417 trees per hectare) close on a typical small rural landholding

Figure 21 Moderate space plantation at Lorum (6m x 3m) with vigorous weed growth under trees.

Growers can also space trees in a more rectangular arrangement at (8m x 3m) that reduces the number of rows that need to be cut through the bush and can allow for gardens to be grown between tree rows for an extended period of time. This moderate spacing can be an efficient design that allows growers to mix tree plantations with other land uses. In the wider inter-row can lead to large branches that may require early pruning. The closer spacing of the trees in the row (3m) can help to reduce weed growth under trees. In the moderately spaced plantings thinning will still need to be undertaken in the first five years to allow the trees to continue to develop a rapid rate.

Low density, widely spaced plantations

Many of the agroforestry plantings of whitewood are established at wide spacing, below 300 trees per hectares, to allow other land use options to be undertaken (Figure 22). In these systems the trees are often integrated into agricultural production, most often based on coconuts (Figure 24), cropping or livestock. The trees in widely spaced systems will need to be pruned to ensure that the large branches in the lower part of the stem do not reduce the value of the log significantly.

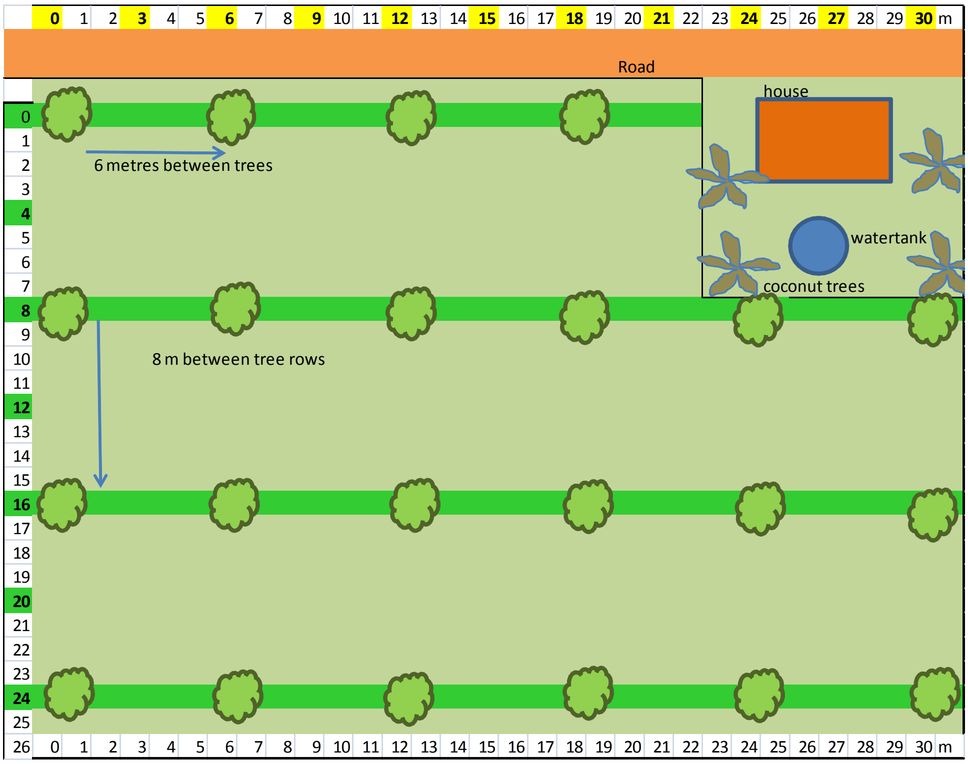

Figure 22 A plan view of a widely spaced whitewood planting (8m between rows and 6m between trees- 240 trees per hectare) close on a typical small rural landholding

Figure 23 Whitewood trees at three and a half years old established at wide spacing (300 stems per hectare) amongst mature coconuts, and grazed by livestock.

Yield from plantation

Establishment practices

The early stages of the plantation, the first 12to 24 months, are often referred to as the establishment phase. During the establishment phase growers need to focus on ensuring seedling survival and rapid growth. It is in these early stages that trees are very vulnerable and risks of failure are greatest (West 2006). Before seedlings are planted out the site needs to be prepared, this often involves some clearing of the site and setting out the planting rows.

The methods used to plant and establish plantations will be influenced by the conditions at the site and risks posed by erosion, livestock, pests and the presence of existing vegetation. Prior to planting, once vegetation may has been removed to allow planting, fences may need to be built to exclude livestock, roads and track built to allow access. If there are creeks or drains, some consideration of crossing such features will need to be considered.

In steep or rocky sites, the risks of movement of soil and debris may mean that disturbance of the sites may need to be reduced. In such cases, where cultivation is not possible or sensible, trees will need to be planted with a minimum disturbance. In areas prone to mass movement or erosion existing vegetation may be best retained or very carefully removed from the site to ensure that soil is not exposed to erosion.

Site Preparation- Cutting Lines

The most common site preparation method at present in Vanuatu is to cut lines through existing weed infested areas and light bush (Figure 25). The lines are often cut with a bushknife, the distance between rows is dependent on the spacing required. The lines are a low impact and low cost way of providing space for young trees to be planted. The cutting of lines provides excellent shelter for young trees, particularly at the hot dry times of the year, where the soil can heat up and dry out if all the vegetation is removed from the site. However, the cutting of lines through areas infested with Merrimia will place the trees at high risk of being suppressed, damaged or killed by smothering from wines and woody weeds such as pekoe.

Figure 24 Lines cut through light bust for planting of woodlot trees.

Site Preparation- Mechanical

In larger-scale forestry projects, often sites are cleared using mechanical methods such as large tractors (Figure 26). This can be a very quick and efficient way of clearing weeds prior to planting. The exposure of the soil to the sun in this type of preparation can cause young trees to experience water stress if conditions after planting are hot.

Figure 25 Using large tractors to clear a site prior to planting.

Weed control

Weed control is possibly the most important aspect of establishment silviculture, after site selection, in the tropics. Weed growth, especially of vines (eg. *Merremia peltata*) in the tropics is extremely rapid and these can overtop and adversely affect the growth of the young plantation through direct competition, and in the case of vines, through twining and overtopping the trees. Manual tending is currently used as the method of both weed and vine control and this must be carried out regularly. Hand tending is required on at least a two to five weeks rotation in Vanuatu (Figure 27). The time between hand tending weeds is largely dependent on the time of the year and the rainfall. This simple weed control system can be hard to manage due to the difficulty of having personnel available to cover the area when required, since manual control is a tedious slow process. The use of chemicals like glyphosate in weed control is an integral part of forestry weed control management in many plantation systems; however the costs, high rainfall and the training make the safe use of chemical challenging.

Figure 26 Cutting Lines and hand tending weeds is the current standard method of controlling weeds in Vanuatu.

The use of non-residual chemicals (glyphosate) in the immediate vicinity of the tree was found to be of limited success for merrimia control, given the waxy surface of the leaves and the speed with which the vine grows. In the In larger commercial plantations the use of broad-scale mechanical and chemical weed control may be required to make sure that large areas can be adequately managed. Another method of controlling weeds is to use livestock to control the vines and to encourage grass once the trees are large enough to withstand the movement of cattle. It is important to not keep cattle in the plantings too long, to avoid overgrazing and compaction around the base of shallow rooted trees.

Silvicultural Management of whitewood in timber plantation systems; opportunities to improve growth rates and wood quality

The value of a planted forest is often measured in the value of the wood products or the environmental services they provide. The faster the trees grow the earlier the wood can be harvested, or the greater the environmental services provided. Improvements in plantation management will often provide direct improvements in growth, increasing the volume of wood produced at a given age. In this chapter the plantation management systems required primarily for timber production will be discussed.

In timber production systems the age of harvest, the types of wood products and the costs of growing the timber will largely determine the economic performance of the plantation. Therefore, growers most often aim to grow wood as rapidly and cheaply as possible. The more challenging part of growing timber is to improve the quality of the wood. While the wood properties of young whitewood trees (10-12 years old) appears to be similar to that of mature trees (Doran *et al.* in press), growers need to understand the importance of wood quality. Generally in plantation forestry, including whitewood, the main impact on wood quality will be the size of the logs and the presence of defects. Growers have a significant degree of control over both the size of the logs and the presence of knots. The size of individual trees can be improved through thinning and pruning.

Measuring plantation tree growth

Measurement of tree growth is an important part of any plantation program, to help determine productivity (Figure 28). Mean annual increment (MAI- in cubic metres of wood per hectare/ per year) is the average rate of production at a given age. In Vanuatu the MAI is in the order of $20m^3$/ha/yr (Grant *et al.* 2011) this figure is based on the volume of wood divided by the age of the plantation in cubic metres of wood per hectare per year across sites on Santo. The growth of a whitewood, like all plantations, tends to start relatively slowly as the trees establish then the maximum growth rate occurs from about seven years to 16 years (Figure 29). At the 16 year mark generally there is about 250-350m^3 of timber volume per hectare (Growth Chart in Appendix 2).

Figure 27 Measuring diameters at breast height (DBH) of a young whitewood woodlot

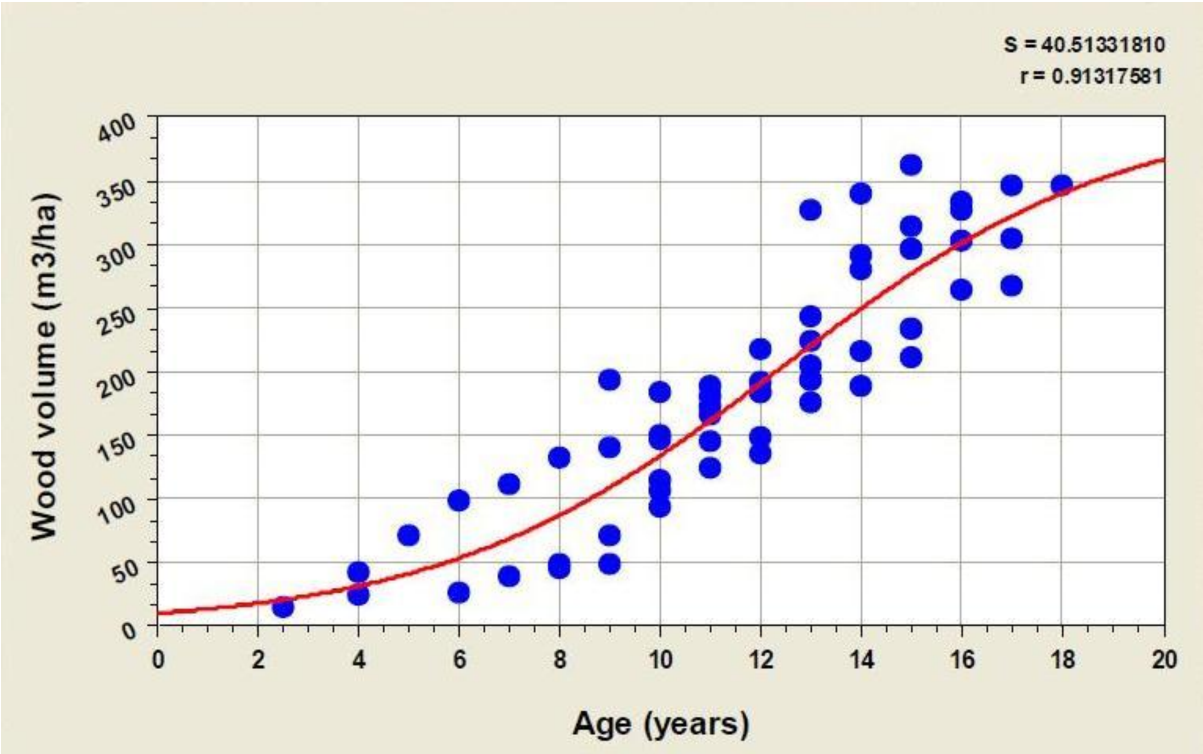

Figure 28 Growth of Whitewood plantations on Santo (From Grant et al. 2011).

Improving plantation growth

As discussed earlier, to establish a productive plantation, young trees are grown in a nursery, then planted out, often in rows where weeds are removed and the tree rows kept weed free. As the trees grow and their leaves and branches develop a canopy that begins to shade out the weeds or any other plants grown nearby. Below ground the roots grow in search of nutrients and moisture to keep the trees healthy and productive. The continued growth in the biomass of the trees will be determined by the availability of adequate light, water and nutrients at the site. There is a limit to the amount of plant growth that can be supported on any site. As such, the removal of weeds and trees of low commercial value is often undertaken in well managed commercial plantations to allow resources to be available to the higher value crop trees. The following section will discuss the role of the number of trees planted initially and the silvicultural management (fertilising, thinning and pruning) in maximising plantation growth.

Fertiliser application

In many parts of the world the application of fertiliser at plantation establishment can in many cases dramatically improve both the initial performance of the plantation, and this growth advantage can be maintained throughout the rotation. However, in the trials conducted on Santo by ACIAR, fertiliser has not shown to have a noticeable improvement in tree growth. The high fertility of the soils in many parts of Vanuatu means that the use of fertiliser may not be warranted.

But in those areas where soils are degraded or soil fertility is naturally low fertiliser may have a very important role to play in establishing a healthy and productive plantation. A good early growth response by the planted stock also allows trees to more rapidly gain control of the site, reducing the opportunity for weeds to affect plantation development and in many cases reducing the number of weed control operations required. Correct plantation nutrition also has an effect on wood quality and plantation health with a healthy plantation at a much reduced risk of attack from insects and pathogens (Lawson per comm.). The effects of both fertiliser application and weed control can be affected by site preparation and there is often an interaction between these site establishment components.

Thinning

Thinning is the removal of trees to reduce the stand density (the number of trees per hectare), therefore reducing competition and increasing growth on the most valuable trees. By reducing the number of stems per hectare and getting rid of the low value stems, the growth across the site will also tend to improve wood quality and economic value of the timber. Well considered thinning will also significantly reduce the time taken to produce large diameter sawlogs (West 2006). Thinning regimes will be influenced by the initial spacing of trees and the rate at which the plantation grows. Thinning can be a significant challenge for plantation managers, who find it hard to cut down trees that have been carefully tended. Thinning throws up some very important and tricky questions that need to be carefully considered:

- At what age is the stand to be first thinned?
- How many trees need to be removed to get a good thinning growth response from the remaining stems?
- Which particular trees should be removed?
- How many times during the life of a plantation should thinning be undertaken?

The answer to these questions is often difficult to predict, particularly when the species is fairly new to plantation forestry. So forestry managers often need to make decisions as the stand develops.

When to thin?

The decision about when to first thin is often taken when the annual growth in stem diameter of the trees slows down due to strong competition. In many plantation systems the first thinning even is timed to coincide with the closure of the canopy, which is when the crowns of the trees begin to overlap. Another way to determine when thinning should occur is to measure the diameter of trees on a regular basis (every 6-12 months) and remove trees when the diameter increments begin to slow down. This is often in the first 3-5 years after planting, just after the floor of the plantation has been shaded out by the canopies of the trees, this point is often described as “site capture”. At this point the trees tend to begin to shed the leaves and branches that are shaded. This natural process of “branch shedding” can be used to reduce the costs of pruning in whitewood planted at close spacing.

For sawlog production the rule of thumb is “*to thin hard and thin early”.* However, heavy thinning in areas where strong winds and high rainfall occur exposes the plantation to increased risks of wind damage and can increase the treats to growth posed by weeds such as merrimia. In some stands, mean tree volumes for whitewood have been shown to improve by over 300% through manipulation of spacing and thinning treatments (Aru and Robson, 2005). Whilst the application of such stand management will not yield such dramatic results across an entire estate, this figure does underline the opportunities presented by well timed thinning regimes. (A suggested thinning regime for a whitewood timber planting is provided in **Appendix 1** for a closely spaced plantation over a 15 year period.)

Figure 29 "Site capture" in a 2 year old planting, where the shade from the canopy of the whitewood trees suppresses weed growth.

Tree selection

In carrying out thinning the aim is to select the highest quality trees to be retained, this provides managers with the opportunity to select trees with a number of traits:

- Have good form- that is the trees with a single well formed leader
- Good quality straight stems, free of major defects and large lower branches.
- Trees with good crowns and have shown vigorous growth rates.
- Trees that are fairly evenly spaced and well positioned-to ensure that the trees are as evenly distributed across the site as possible.

Designing plantations to help reduce negative impacts of thinning

The most common method of thinning is selective thinning, where the best trees are retained regardless of where they are located in the stand. Growers can consider a few key points when looking to conduct efficient thinning operations.

- Spacing can help to reduce the damage to remaining trees when thinning- A wide inter row area can assist in the removal of trees at thinning, by creating wide corridors to fell trees into. Whitewood is a large spreading tree so felling trees can cause damage to surrounding trees. If there is a slope on the site trees will tend to felled down the slope, staring at the bottom of the hill and working your way up the slope.

Another method of thinning is **systematic thinning**- this type of thinning is when a whole row of trees is removed, regardless of the condition of the trees, all trees good and bad are cut out. Often in a plantation every third row may be removed or every second tree within a row. Systematic thinning is cheap and can reduce the damage to retained trees.

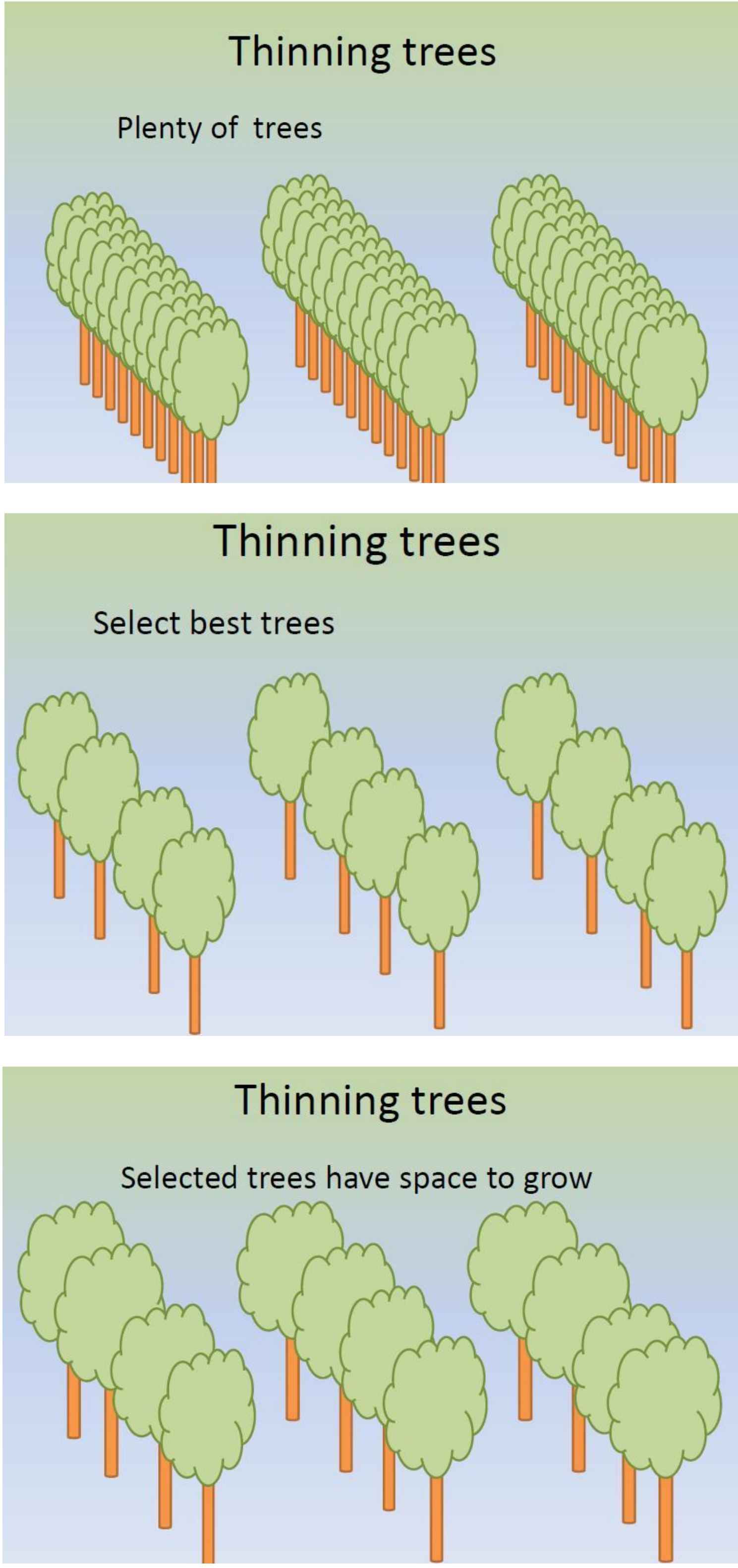

Figure 30 General principles of thinning, where trees in a plantation are spaced close together for the first 3-5 years then the trees are thinned to allow the best trees to grow into large diameter logs as quickly as possible.

Pruning- the key to improving wood quality

The quality and price paid for logs is often a function of the properties of the wood, in particular the presence of defects and knots. Knots are the result of sawing through wood where a branch has been formed. Knots are the most common features that will reduce the value of sawn wood. Pruning of young plantation trees is used to reduce the presence of knots and to ensure the recovery of clear wood is maximised.

The market pays a premium wood is free of any major knots and defects. Therefore, one of the most important things a plantation grower will need to do is to prune carefully. Growers need to consider the time at which to prune, and to how much to prune. The difficulty is that trees need branches and leaves to grow, so pruning will tend to slow down the growth of trees if too much material is removed at one time.

Whitewood is a not a very shade tolerant species, and so leaves and branches die rapidly once heavily shaded, and the dead branches are readily shed. While this can be a very favourable attribute for a plantation species, it may lead to some defects in the log. Pruning should be aimed at removing live branches where ever possible, once branches die there is a risk of decay entering the stem of the tree and causing a significant defect.

Figure 31 Pruning live branches in four year old trees in an open planted whitewood woodlot at Jubilee Farm.

If the grower is able to get a premium for trees that have been heavily pruned, it may pay to remove the maximum number of branches to ensure that there are very few knots in the lower stem of the trees. Pruning studies around the world have indicated that the tree growth will be reduced significantly as the proportions of branches are reduced exceeds 50% (Figure 33) of the crown at any one time (West 2006).

It is without doubt that whitewood is a species that requires pruning to produce high value wood from plantations. A general “rule of thumb” for pruning young trees is to leave a minimum of 2 and often 3 whorls of branches to ensure that pruned trees are not left with too little canopy to remain competitive with unpruned trees. Pruning is also a source of entry for fungus and insects into the wounds left by removing the branch. In humid areas like Vanuatu, the pruning could be carried out at the cooler times of the year when the risks posed by fungal infections may be reduced. The question is how to balance the need to prune with the reduction in growth and risks of damage through fungal attach.

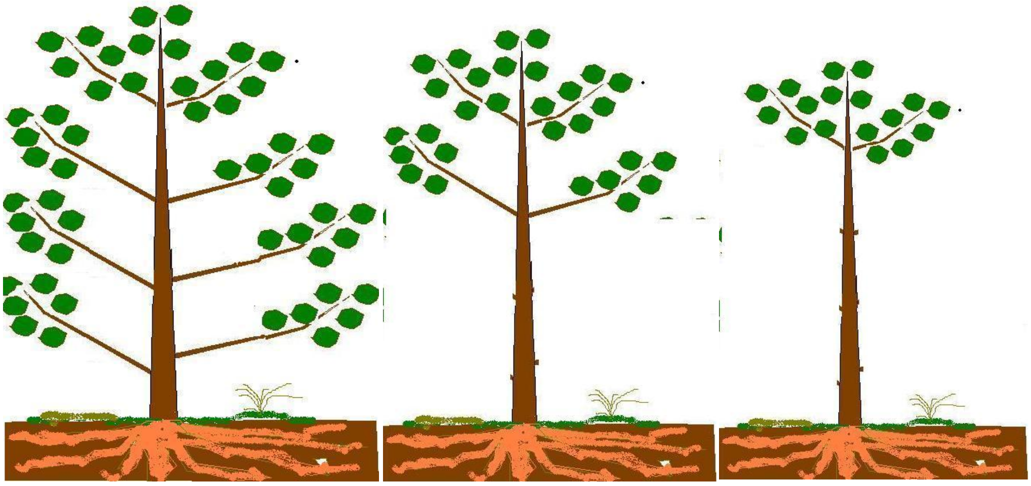

Figure 32 Pruning trees involves the removal of a proportion of the branches. On the left is an unpruned tree with large lower branches. Middle the lower two whorls are removed to leave about 50% of the canopy. On the right the next whorl of branches are removed to leave only 25% of the canopy intact.

At the very extreme end of the pruning scale is the pruning of all branches up the stem of a young whitewood tree (Figure 34). While this method requires a great deal of labour and will slow tree growth significantly and increase the weed control, heavy pruning such as this will produce the very highest quality wood. It remains to be seen if the sale of logs will cover the costs of such pruning regimes. The most common pruning regimes prune logs up to 50% of the total stem height at year 3 and 6 to produce a pruned log of at least 6 metres.

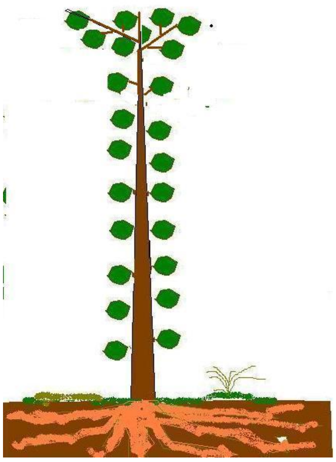

Figure 33 An example of heavy pruning with the removal of all major branches in the young tree to ensure no knots in the lower log.

Not every tree in a plantation needs to be pruned

In most sawlog regimes the thinning will be conducted to produce 150 to 300 sawlogs in the final stocking. If that is the case then some trees will be removed from the stand. In such cases, only the trees that are going to retained for sawlogs may need to be pruned, unfortunately this sets up a challenge for growers. The challenge is that pruned trees will grow less than unpruned trees, so the valuable pruned trees may fall behind the unpruned trees. This is a further argument for a regime that involves a number of pruning events that removes a smaller proportion of the canopy. While this may add to pruning costs it may be a way of making sure that pruned trees are not left behind and shaded out by unpruned and less valuable trees.

Other species for consideration in timber plantations with whitewood

Natapoa- Terminalia catappa

This is a fast growing species adapted to a range of soils and conditions including coastal sites. Natapoa has been shown to be a fast growing species, with an open crown and very good stem form (stem straightness) (Figure 35). The tree produces an excellent quality hardwood, used for furniture, appearance and decorative products such as panelling. Natapoa is an excellent agroforestry tree because it provides an edible and nutritious nut as well as a high value sawn timber.

Figure 34 A 12 year old Natapoa tree (Terminalia catappa) at IFP near Shark Bay (left). A young Natapoa (less than 12 months old) in mixed species planting at Jubilee Farm in 2010 (right).

Natapoa forms a straight bole (stem) with branches produced in tiers or whorls of 5-6 branches and a long inter-node between branches. Branches tend to self prune well in plantation conditions where trees are more closely spaced. The trees tend to tolerate strong winds and adapted to withstand tropical cyclones well (Thompson and Evans 2006). Natapoa is an excellent species for inclusion in agroforestry intercropping systems due to the range of uses including fuelwood, shade and windbreaks.

Timber of Natapoa

The wood of Natapoa is highly sought after for a range of uses including, boat building, furniture, traditional canoes and drums, plywood, construction and panelling. The wood is reddish-brown of light to medium density (550kg/m^3- air dry density) (Thompson and Evans 2006). The wood is easy to dry and can be used internally only. Timber not to be used in condition where it is in contact with ground.

Silviculture of Natapoa

Natapoa is a fast growing species that will require moderate initial spacing of 450-650 stems per hectare (5m x 3m to 8m x 3m). The higher stocking will reduce the weeding costs, there will be a need for some thinning when young. At year 5-7 an initial thinning to 250- 350 stem per hectare will be required. A final stocking for high value sawlogs will be in the order of 150-250 stems per hectare at year 15. The rotation for high value sawlogs will be 25-30 years or longer for high value veneer logs.

Natapoa has some pests, such as wood borers which can lead to significant damage to young trees (Figure 36). The leaves of Natapoa can also be defoliated by a range on insects, which tend to only cause superficial damage.

Figure 35 Young Natapoa tree with damage to stem from borers.

Agroforestry systems using whitewood.

Whitewood can be an integral part of mixed species systems that can confer a range of benefits to communities. The rural populations of Vanuatu engage in subsistence agriculture augmented by fishing and rearing of livestock. Since the 19th century new cash crops have been introduced (cotton, cocoa, coffee, etc.), coconut plantations have been established, and small cash stores have been opened in all the villages. The main current exports are copra, fish, beef and also cocoa (Walter and Lebot 2007) and timber is now a small cash crop and export earner. Timber from rural woodlots has the potential to generate economic benefits. However, the planting of whitewood by rural landholders has been slow to date, whilst there is considerable interest in timber production the successful integration of timber with agricultural production will need to clearly demonstrated.

Community mixed species woodlots

Agroforestry systems and community woodlots can provide a range of benefits including a yield of root crops, including kava, cassava and taro, from two years after planting and of Flueggea poles from six to eight years will provide short term income whilst waiting for whitewood plantations to mature (Figure 37). These will overcome the oft-cited objection to investment in plantations, that income is be derived far into the future.

Given the possibilities of serious insect and disease problems with a native species in the tropics, we believe it is essential to plant mixtures. While whitewood has great potential, alternative species need to be tested and mixed with it. Vanuatu's fertile soils and year-round rainfall provide an ideal environment for producing crops of cassava, taro and kava (Figure 38 and 39). Agroforestry systems with these crops combined with the whitewood are a way to gain short-term income as well as suppress weeds amongst the establishing trees. Some of the yields can be sold locally, as well as being exported to a growing market overseas.

Apart from whitewood production, mixed species systems can develop short-term income sources from Namamou (Flueggea) poles and root crops, particularly taro, cassava, and kava. The establishment of these crops in between the rows of whitewood will suppress weed growth, which otherwise would consume considerable resources to manage, and provide cash for plantation owners much sooner than will the primary timber tree. Flueggea alone, at $2 per lineal metre, producing 200 four-metre poles per hectare, can yield $1600 income per ha at six to eight years of age (Robson, 2005). Given the potential problems with monocultures of a native tree species in the tropics, mixtures using Flueggea and other tree species will "spread the risk" of investing purely in one species.

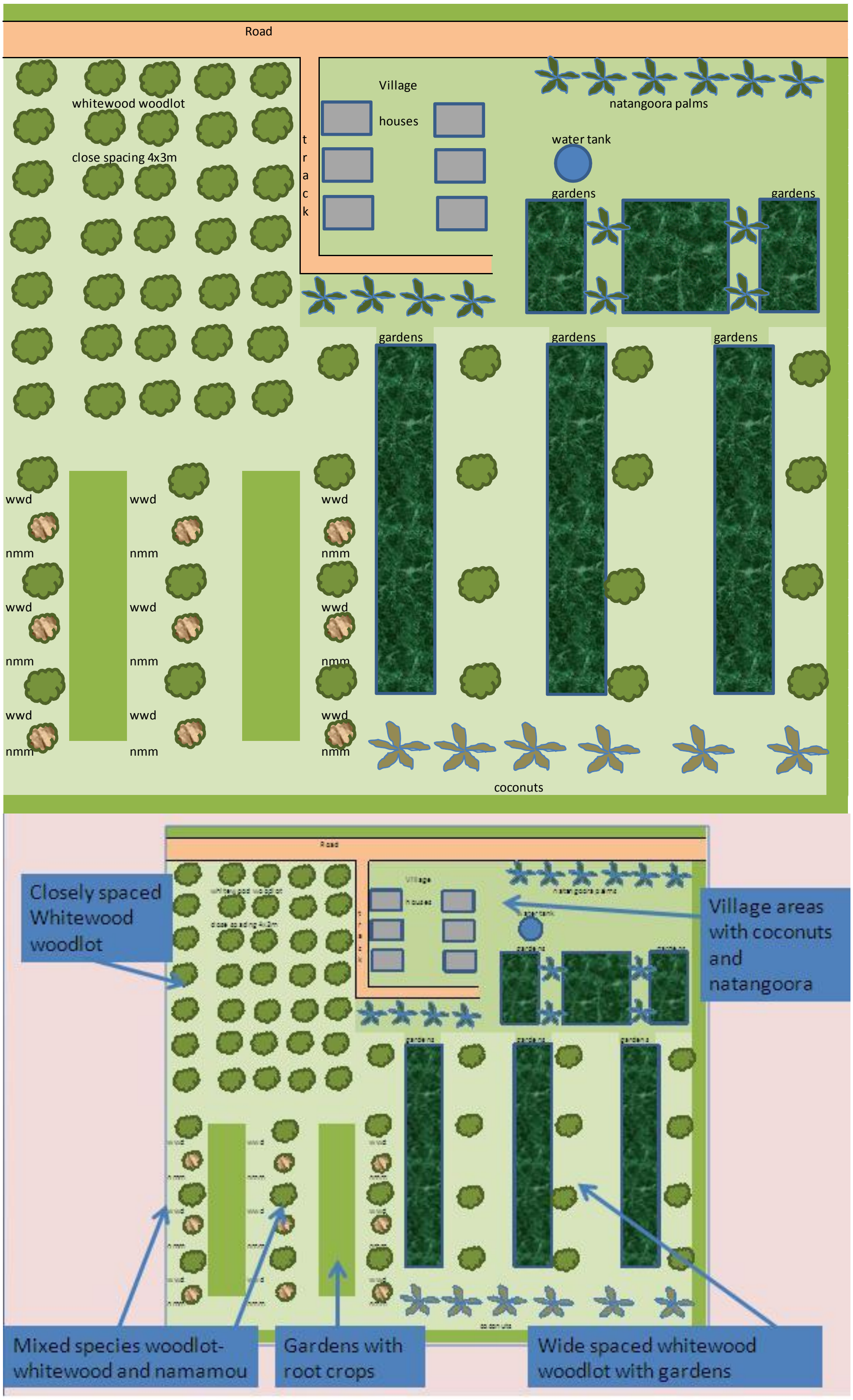

Figure 36 Agroforestry that incorporates a range of elements of closely spaced woodlots, mixed species woodlot and wide spaced agroforestry systems in one small area.

There is a strong need for economic analysis of mixed plantations to take place, as most research has focussed on tree growth and interactions (Nichols et al., 2006). It is possible to get a very complex mix of products from a well designed agroforestry system that may incorporate a range of elements (Figure 40).

Figure 37 Harvesting trees from a 12 year old plantation at Sara.

Figure 38 Whitewood in agroforestry situations with other crops and other tree species, such as natapoa on left.

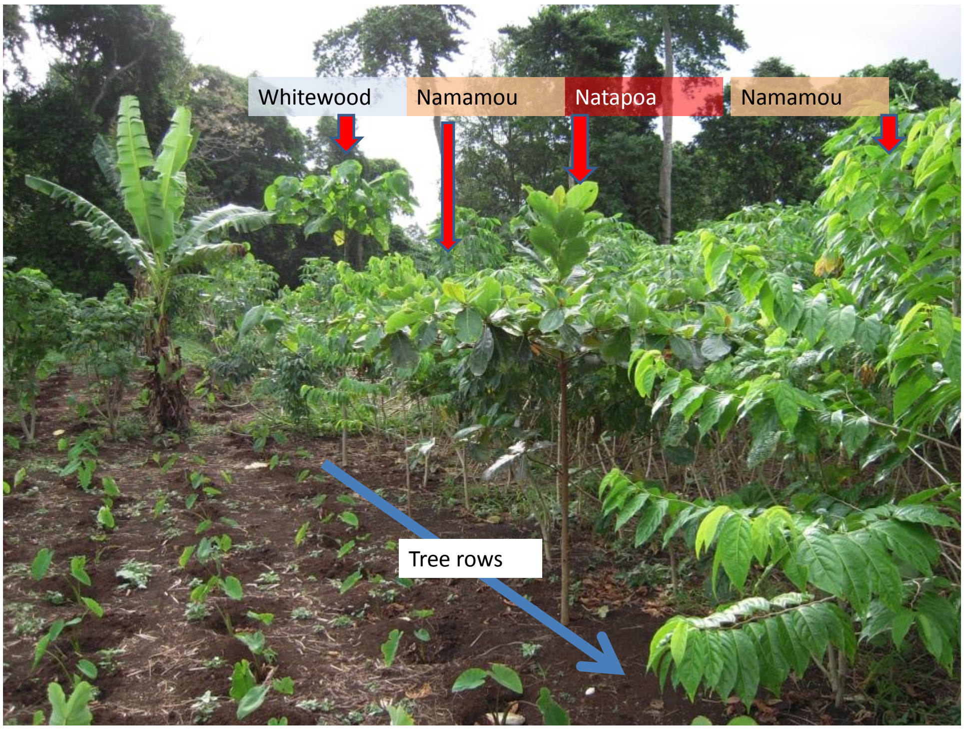

Figure 39 Mixed species rows at Jubilee Farm including whitewood, natapoa and namamou in mixtures along tree rows

Whitewood growers and the needs of the markets

World markets for wood are becoming increasingly discriminating of the quality of the wood they are sold (West 2006). Wood can be used in its more traditional forms or it can be used in engineered wood products where the wood is reduced to smaller components and reconstituted. The major wood products identified by Bowyer et al. 2003 represent a range of potential end uses for whitewood:

- Timber- sawn wood for construction, furniture (joinery), panelling, packing, pallets, sleepers. Timber is most commonly dried before sale for construction and furniture uses.
- Plywood- panel products consisting of thin veneers (1-3mm) of wood glued together to form sheets used in construction and joinery.
- Particle board- pressed and glued particles of wood that are laid into sheets of varied properties depending on the utilisation.
- Other Fibre products- hardboard products, insulation boards.
- Round wood products- these include poles and posts, where the stem is cut into lengths and treated with chemicals that protect the wood from insects, moisture and decay by fungus.
- Paper and fibre-wood is the major feedstock for pulp, packaging and papermaking
- Fuel – wood is often used for cooking heating and the drying of agricultural products such as copra. Wood can also be converted to liquid fuels such as ethanol and biodiesel.

The wood of whitewood is of commercial value, having very good machining properties, rather soft and lower density (365-450 kg/m3 air-dry density @ 12% moisture content). The wood has low strength properties and is not durable in the ground (Keating & Bolza 1982, Thomson 2006), unless treated with preservatives. The wood works and dries easily and is readily treated with chemicals and stains, making it suitable for many purposes including mouldings, boards, joinery, furniture and for veneer and plywood manufacture (Gunn et al. 2004).

Figure 40 Loading of harvested logs from a 15 year old whitewood plantation at Loro

Availability of whitewood

Annual harvesting of whitewood (60-70 % of all logs harvested) and milk tree (Antiaris toxicara) averaged 30,000 m3 between 1990 and 2004 but declined dramatically in 2004 (Figure 42). This was because it has been unsustainably commercially exploited in most parts of its natural range to the point where it now occurs at very low frequency or has disappeared from all but the most inaccessible stands (Vutilolo et al. 2008). By 2008, whitewood accounted for only 20% of the wood harvested (Page 2009). Dwindling supplies of whitewood logs has reduced important export income and has lead to the importation of most timber needed by the domestic market (Mele 2011).

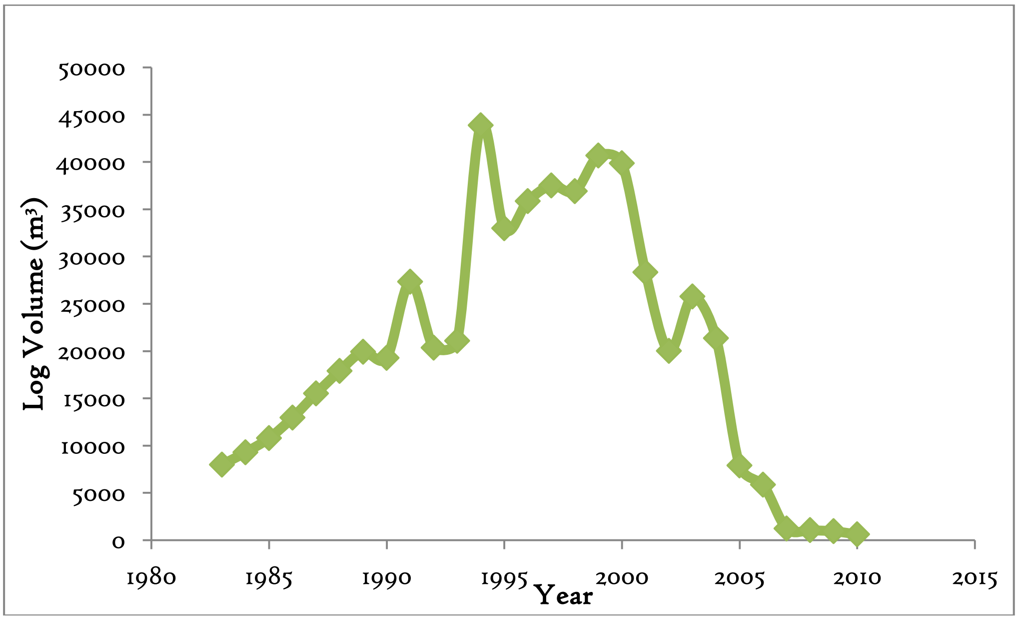

Figure 41 Log Volume Production 1980 to the present (Source Vira 2012)

The future of the whitewood industry largely lies with selling to export markets, where the timber's particular attributes can command price premiums which are not available as a general light construction timber sold on domestic markets. The local market for quality lighter coloured timbers for interior application is not sufficiently large upon which to base an industry or a large plantation estate.

Plantation and woodlot establishment and agroforestry is seen as crucial for ensuring an ongoing supply of forest products to support sustainable livelihoods in Vanuatu. A target of 20,000 ha of plantations and woodlots (the total area of plantations was estimated at 4,800 ha in 2006) by the year 2020 has been advocated by Vanuatu Forest Policy (Anon 2011, Mele 2011). Whitewood has been identified in this Policy as a key candidate plantation species with good timber properties at a young age (rotation length of 15 years proposed) coupled with rapid growth rate, high cyclone resistance, relative freedom from serious pests and diseases and an established export market to Japan (Nichols et al. 2011). Despite its market potential, planting of whitewood woodlots has been slow (less than 500 ha planted to date). Espiritu Santo Island has land available and highly suitable for plantation development, however Nichols et al. (2011) suggests that increased training of land-holders in all aspects of the value-chain for whitewood and the promotion/adoption of community forestry principles is the preferred way to facilitate increased establishment of whitewood woodlots.

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Appendix 1- Thinning regime for a whitewood timber plantation

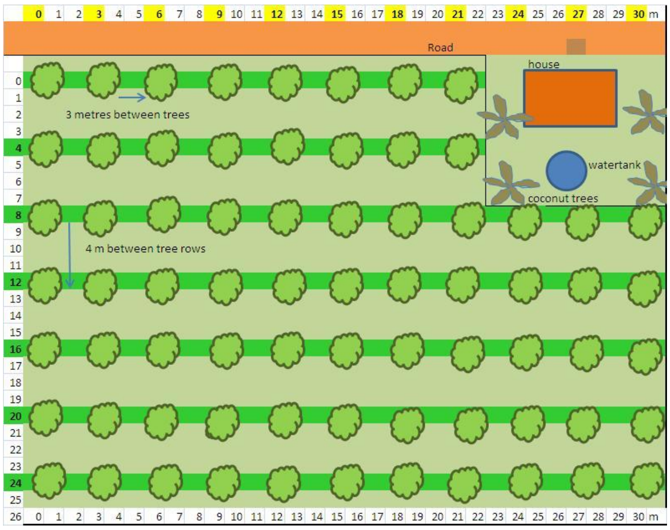


Figure 42 diagram of a 4x3m planting at yr1 (833 trees per ha).

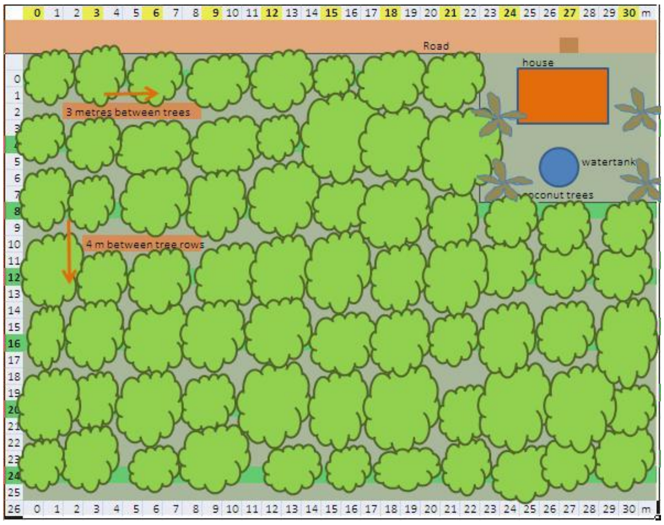


Figure 43 Diagram of a 4x3 planting at yr 3 (heavy competition at 833 trees per hectare can reduce diameter growth).

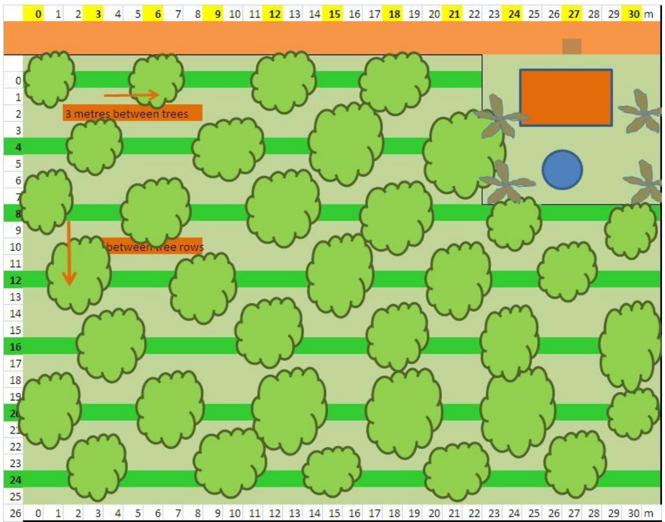


Figure 44 Heavy competition is reduced by a thinning at yr 3 to reduce the stocking to around 400 trees per hectare.

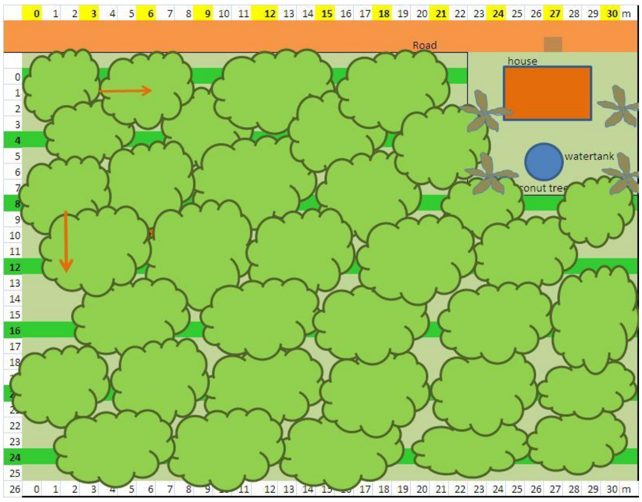


Figure 45 Tree growth at year7 after thinning at year 3 to a stocking of 400 trees per hectare (Competition between trees may require another thinning of small sawlogs and poles.)

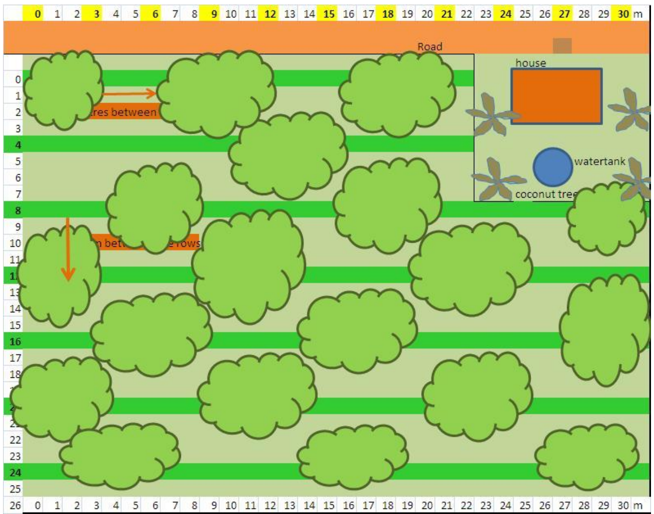


Figure 46 Thinning at 7 years to reduce the stocking to approximately 250 trees per hectare.

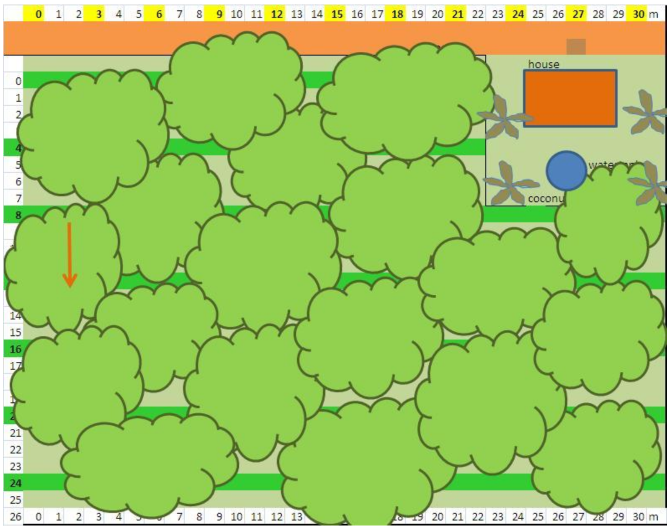
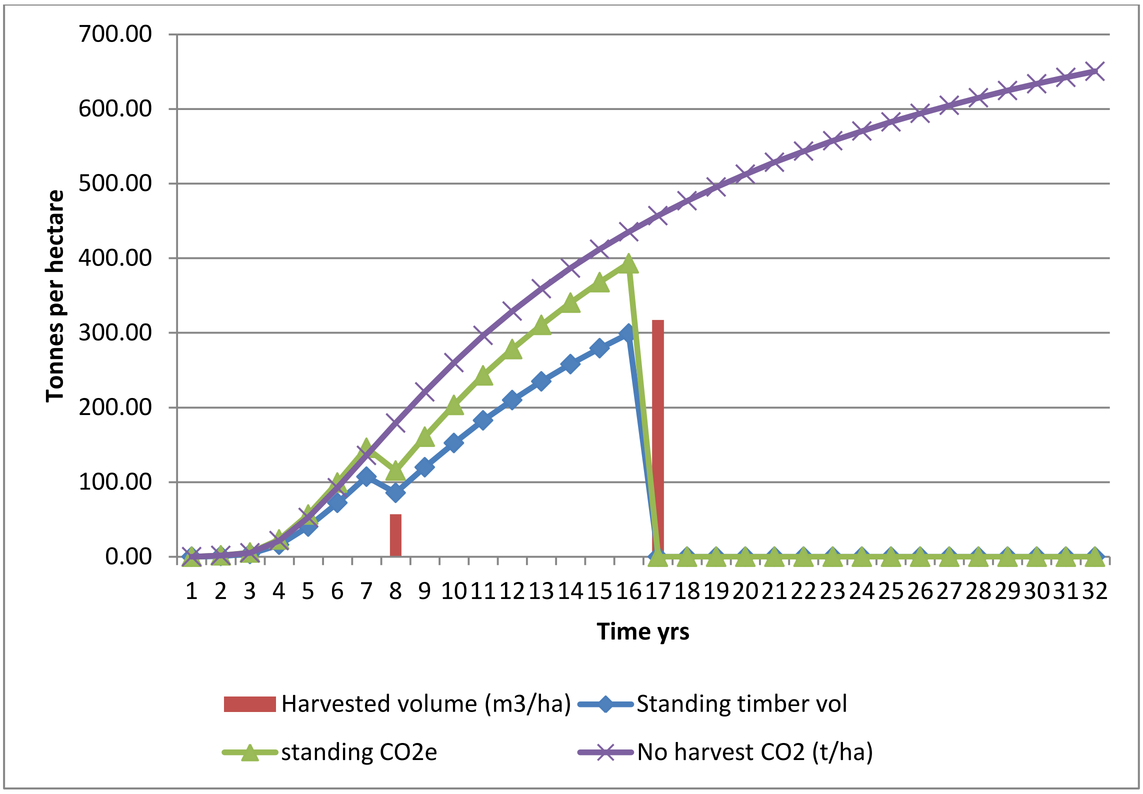


Figure 47 Tree growth at year 15, when a harvest for sawlogs and veneer logs may be undertaken (Volume about 250-300 cubic metres per hectare).

Appendix 2 Carbon and timber production over a rotation with thinning and pruning.



Appendix 3 Modelling of growth and income over 15 years under 3 different management regimes

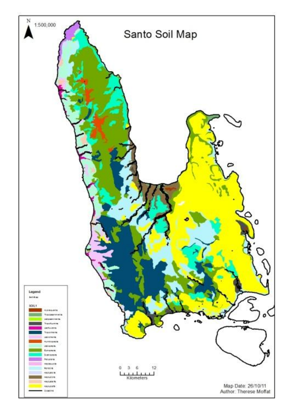
																Total over rotation
Project year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
calendar year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
growth volume (m3/ha) without thinning	0	1.0	3.7	16.0	40.3	72.1	107.2	142.6	176.9	209.3	239.7	266.8	291.9	315.0	336.3	356.0
Increment	0	1.0	2.7	12.3	24.3	31.8	35.0	35.4	34.3	32.5	30.3	27.2	25.1	23.1	21.3	19.7
Thinned and Pruned																
Thin %	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	40%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	100%
cleaned thin	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	1
Harvested volume (m3/ha)	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	299
standing volume (m3/ha)	0	1	4	16	40	72	107	86	120	152	183	210	235	258	279	299
Product recovery (m3/ha	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	50%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	60%
Product value ($/m3)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	40	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	80
Harvest income ($/ha)	0	0	0	0	0	0	0	$ 1,141	0	0	0	0	0	0	0	$ 14,352
Thinned no pruning																
Thin %	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	40%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	100%
cleaned thin	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	1
Harvested volume (m3/ha)	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0	295
standing volume (m3/ha)	0	1	4	16	40	72	106	84	118	149	178	206	231	254	275	0
Product recovery (m3/ha	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.6
Product value ($/m3)	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	30	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	60
Harvest income ($/ha)	0	0	0	0	0	0	0	$ 843	0	0	0	0	0	0	0	$ 10,613
no pruning no thinning																
Thin %	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1
Cleaned thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Harvested volume (m3/ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	313
standing volume (m3/ha)	0	1.0032125	3.4949475	14.608545	36.348731	64.828109	95.143995	125.80995	155.47942	183.50781	209.64507	233.85244	256.19872	276.80309	295.80399	0
Product recovery (m3/ha)	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	$ 1
Product value ($/m3)	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	40	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	40
Harvest income ($/ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$ 6,267

Figure 48 Modelling of income from 1 hectare of whitewood managed under 3 different regimes- 1- Thinned and pruned, 2- thinned no pruning, and 3- No thinning no pruning

Department of Forest

Growing Waetwud in Vanuatu

ACIAR Waetwud Projeck



Space bitwin yang tris i save affektem o kintribute long gro blong ol tris. Tris we oli planem klosap long 4x3 mita bai save kompit wetem olgeta mo makem tri i save gru slow long taem supos i no gat thinning i tekem ples. Planem tris long wan gud wide spacing olsem 10 x 5m hui i save sivim plante rum blong ol trees i save gr emia nomo ol tris i save givim bijfala branch/han mo tu ol rubis gras/wid i save kam plante tu.

Mixim tris

Mixim o planem ol differen tris tugeta i makem se fama i save planem differen prodaks long wan smol wudlot o plantesen. Mixim o planem ol differen tris tugeta i save prodiusem lokol timba, nuts mo save expotem timba prodak.

Wood Kwality

ACIAR Projeck emi bin millim sam waetwud we oli planem long wan smol plantesen blong finemaot kwality blong wud. Wan maen lukluk o tingting blong Mill study ia emi blong luk hamas wud i save kamaot long wan log mo blong finemaot ol grade blong wan sawn timba. Grading blong sawn timba nao baibai i givimaot o telemaot market praes mo baibai emia nao bai i soem long praes blong wan log o wud.

Agroforestry

Planem tris wetem ol narafala krops o kaikai blong i save providem extra mani long ol tris we yu planem insaed long garen. Timba tri o tri blong timba yu save planem wetem kokonut tu.

Southern Cross UNIVERSITY
A new way to think

Sapos yu wantem moa infomesen long Waet wud yu save Kontaktem Dipatmen blong Forestri long Santo blong oli save helpem yu.

Forest Department
PMB 004
Luganville, Santo
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ACIAR

Lorum Silvicultural Trial

Lorum silvicultural trials treatment schedule

Spacing and thinning trial

Plot	Gross plot size	Spacing	Fertiliser	Thinning
1	45m x 32m	8x3	NPK+	1
2	40m x 32m	8x2	NPK	1
3	30m x 32m	4x3	NoFert	1
4	45m x 32m	8x3	NPK+	2
5	30m x 32m	4x3	NoFert	2
6	40m x 32m	8x2	NPK	2
7	45m x 32m	8x3	NPK	2
8	40m x 32m	8x2	NoFert	2
9	30m x 32m	4x3	Double NPK+	2
11	30m x 32m	4x3	Double NPK+	1
12	40m x 32m	8x2	NoFert	1
13	45m x 32m	8x3	NPK	1
17	45m x 32m	8x3	NoFert	1
18	30m x 32m	4x3	NPK	1
19	45m x 32m	8x3	NoFert	2
20	30m x 32m	4x3	NPK+	2
21	40m x 32m	8x2	Double NPK+	2
22	30m x 32m	4x3	NPK+	1
23	40m x 32m	8x2	Double NPK+	1
24	40m x 32m	8x2	NPK+	1
25	45m x 32m	8x3	Double NPK+	1
26	40m x 32m	8x2	NPK+	2
27	45m x 32m	8x3	Double NPK+	2
28	30m x 32m	4x3	NPK	2
29	45m x 32m	8x3	Ripping	1
30	45m x 32m	8x3	Ripping	2

Fertiliser/weed control levels

Plot		Gross size	Spacing	Fertiliser	Weeding
10a	north	24m x 32m	4x2	Triple NPK+	1m knife
10b	east	24m x 32m	4x2	Triple NPK+	1m glyphosate
10c	south	24m x 32m	4x2	NPK+	1m knife
10d	west	24m x 32m	4x2	NPK+	1m glyphosate
14a	north	24m x 32m	4x2	Triple NPK+	1m glyphosate
14b	east	24m x 32m	4x2	NPK+	1m glyphosate
14c	south	24m x 32m	4x2	Triple NPK+	1m knife
14d	west	24m x 32m	4x2	NPK+	1m knife
15a	north	24m x 32m	4x2	Triple NPK+	1m glyphosate
15b	east	24m x 32m	4x2	Triple NPK+	1m knife
15c	south	24m x 32m	4x2	NPK+	1m glyphosate
15d	west	24m x 32m	4x2	NPK+	1m knife
16a	north	24m x 32m	4x2	NPK+	1m glyphosate
16b	east	24m x 32m	4x2	Triple NPK+	1m glyphosate
16c	south	24m x 32m	4x2	Triple NPK+	1m knife
16d	west	24m x 32m	4x2	NPK+	1m knife