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Final Report

Small research and development activity

SRA	**An inventory of wild sandalwood stocks in Vanuatu**
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2 Executive summary

- Characterizing sandalwood (*S. austrocaledonicum)* abundance in Vanuatu is challenging due to the broad, discontinuous yet highly modified distribution of sandalwood and the lack of systematic historical inventories or detailed harvest documentation.
- The preliminary distribution has been estimated from anecdotal ranges provided by the Vanuatu Department of Forests (VDoF), GIS spatial analyses and recorded sandalwood locations collected during the Oil Quality Survey (Page, 2005) and during the 2007 sandalwood inventory survey conducted for this project. Historic densities have been estimated from anecdotal descriptions and harvest data records.
- Current densities are based on the 2007 field survey of sandalwood populations on four Vanuatu islands. The surveys were conducted in regions of known sandalwood populations. The low aggregated density (0.4 trees/ha) of commercially sized trees found in these surveyed populations is a cause for concern. We recommend extending the current survey to Tanna and perhaps northern Santo.
- Based on the field data, we estimate that the current resource on the four islands surveyed is approximately 210 tonnes, with another 80 tonnes estimated on other islands of Vanuatu. At current harvest rates this resource may be quickly depleted and there will be a shortfall until plantation sandalwood is available in 10-15 years.
- Consideration should therefore be given to reducing the quota for wild sandalwood harvest to a sustainable level.
- We recommend the implementation of two purchase registers that clearly record purchases of heartwood and sapwood as separate products. The further development of this monitoring system may be a suitable activity for government or overseas assistance.
- There is a need for accurate and ongoing sandalwood growth and yield data, based on several islands to cover the range of genetic types present. Ideally these growth data should be collected annually at permanent quadrats. Measurements of tree height, diameter at breast height (DBH), basal area at 10cm height and host species should be made using standard forestry techniques.
- There is also a need for systematic recording and archiving of harvest data within the VDoF. Ideally this would be regularly sourced from the buyers and recorded on a standard proforma. The data could be stored both electronically and on paper, and analysed regularly with some form of reporting.
- We support the initiatives of the VDoF and industry to promote plantation establishment on several islands. This will also take harvest pressure away from wild populations of sandalwood. These wild populations need to be protected from over-harvesting and from damage by cattle grazing and trampling.
- The size class distribution over the entire survey area was skewed towards very small seedlings/suckers and saplings. Even at the best sandalwood sites there is a lack of mature trees and the distribution of stem sizes is likewise heavily skewed. The remaining trees occur in small clusters and density per hectare is very low.
- We suggest that the sandalwood genetic resource should be conserved using ex-situ seed conservation techniques. This might be carried out in the private sector as an adjunct to the wider establishment of sandalwood plantations.
- We recommend that VDoF investigate the feasibility of establishing an effective network of sandalwood conservation agreements to conserve representative populations and genetic resources over the species' range in Vanuatu. This might be in exchange for support for plantation establishment.

- The implementation of a planted resource survey, to quantify the extent and maturity of both small holder and investment plantings, will help determine the most appropriate planting models for different economic objectives.
- We recommend the establishment of sandalwood growth plots in conjunction with progressive sandalwood farmers, to quantify the long term productivity of different planting models and across different climatic and edaphic zones.
- There could be further refinement of the mapping of suitable sandalwood habitat across Vanuatu that accommodates both climatic variables and environmental tolerances. Variables such as proximity to transport corridors and ports may also be of use to determine areas suitable for more significant investment in planting sandalwood.

3 Introduction

The heartwood of some sandalwood (*Santalum*) species produces valuable oil that has been prized in Asia for centuries and is used in perfumery internationally. The oil-bearing, powdered wood is the main ingredient in incense joss-sticks. In the Pacific, sandalwood of a number of species was the first item of trade with Asia and Europe and has been exported for almost 200 years. S*antalum austrocaledonicum* was heavily exploited over about three decades in the middle of the 1800s in New Caledonia and Vanuatu, and it has been utilized periodically since. Carvings, sandalwood oil, and incense production, listed in order of highest to lowest value, are the three major present-day wood uses of *S. austrocaledonicum.* Continued high demand and over-exploitation of the natural resource base has lead to a general shortage of sandalwood oil on the international market.

Sandalwood (*S. austrocaledonicum)* is found in the archipelagos of Vanuatu and New Caledonia. In Vanuatu, it occurs predominantly on the western parts of the islands of Santo and Erromango and in lesser quantities on Tanna, Aniwa, Aneityum, Efate, Malekula and Aneityum. The sandalwood industry is dependent on trees of wild origin, although significant planting has occurred on some islands in the last five years.

Following a long period of boom-and-bust in sandalwood export, with many small business failures, the Government of Vanuatu has exerted a level of control on marketing, with only two licences to buy sandalwood to local processors with demonstrated capacity, for up to 80 tonnes of sandalwood per year combined, the current estimated annual sustainable harvest from the native resource. There is a minimum price that must be paid to growers of about AUD8750 per tonne (700vt/kg 'beach price') depending on transport costs. This policy is under regular review by VDOF, particularly in the light of persistent requests to resume unprocessed wood exports to Asia.

The pressure for relaxation of limitations applied to sandalwood harvest has caused the Vanuatu government to become concerned that wild sandalwood stocks may become exhausted. Accordingly, the Vanuatu Agriculture Minister approached the Australian High Commission in Port Vila, requesting a quick and rough census to provide scientific underpinning for a conservation strategy.

3.1 Terms of reference

A report to ACIAR, providing

- A rough inventory of wild sandalwood stocks in Vanuatu, stratified geographically and by size class.
- A critical evaluation of inventory methodology, and recommendations for future inventories.

4 Historical Patterns of Harvesting

4.1 Disclaimer

Due to the perceived sensitivities of information contained within this document, the names of commercial sandalwood buyers have been omitted. The data used in this report relating to historical harvest volumes were collated from the Vanuatu Department of Forests records (VDoF), which includes Sandalwood Purchase Registers, Annual Reports and Export Permits. The data used are the most accurate that could be acquired and is presented objectively in this report to determine the actual volumes of heartwood harvested in Vanuatu. While it is recognised that much of the data is incomplete, the authors of this report have endeavoured to verify its validity with both the Department of Forests and industry stakeholders. Only those data sets which are complete for a specified period have been used in this report.

Owing to the scattered distribution of many sandalwood species there are inherent difficulties in quantifying the resource by conventional systematic survey methods (Applegate, Davis et al. 1990; Kealley 1991; Miscellaneous 1993). In Western Australia a five year sandalwood assessment program was undertaken from 1980-1984. While the Western Australian sandalwood resource is far more extensive than sandalwood in Vanuatu, the high level of investment to carry out the surveys indicates the challenging nature of quantify a sandalwood resource. This current sandalwood inventory provides base data to estimate a sustainable harvest quota and methodology in which future surveys can be easily carried out to monitor changes in the natural populations and the effect of different management strategies.

In Vanuatu the Department of Forests has been proactive in establishing the necessary legislation and administrative procedures to allow for controlled management and monitoring of activities. However further improvements in the implementation of the legislation would greatly assist in allowing more informed and rapid decision making. Improving the management and systematic entry of data related to Purchase Registers, Export Permits and Certificate of Origin would be the most cost-effective way of improving the information source on which decisions can be based. Improved security and systematic backup of these data are essential to secure these very valuable data.

External technical support for the Department of Forests to achieve these recommendations would be a worthwhile investment for the Vanuatu Government or an international donor. The Purchase Registers contain location-specific (village or bush camp) harvest data that are extremely useful in determining the volumes of sandalwood that have been extracted from an area. These data, combined with the inventory data, would improve the calculation of sustainable quotas for specific islands. The majority of Purchase Register data from around 2001 was lost from the Department when a computer was stolen from the offices. During the course of this study the two licensees indicated that they still retain many of the purchase registers either in paper or digital format. It is recommended that the Department of Forests request the licensees resubmit their Purchase Registers and enter them into a database or spreadsheet so it can be used to identify trends.

4.2 Historical Patterns of Harvesting

The extraction and export of sandalwood was the first international commercial industry in Vanuatu which commenced on the island of Erromango in the late 1820s (Shineberg, 1967). The colonial trade in sandalwood, driven primarily by Australian merchants, was exported to China and was unremitting for a period of 30 years (Shineberg, 1967). The sandalwood trade after this period continued sporadically, most likely as populations recovered and small commercial volumes became available. A modest commercial industry has been operating consistently since the 1970s, however there have been recurrent concerns over the sustainability of wild harvesting activities (Neil 1986; Corrigan, Naupa et al. 2000).

In the 1980s the industry was largely unregulated and quantification of annual harvesting across the country was estimated by the exports registered with Vanuatu Department of Customs. There was no requirement for buyers to be licensed and there was little control on the prices being paid to landowners. Concerns of a spike in harvesting in 1986 and 1987 led to a harvest moratorium across Vanuatu from 1988 -1991 to allow the resource to recover.

Following the sandalwood harvest moratorium there was little change in the regulation of harvesting. Far North Timber Sales (FNTS) entered the trade at this time and from 1992 - 1996 this company sourced approximately 20 -25 tonnes annually from the Dillons Bay area of western Erromango.

'The Management and Control of Sandalwood Trade and Exports' Order was enacted in 1997 (No. 3 of 1997) which allowed for improved regulation of the industry. Sandalwood merchants required a license to purchase sandalwood and were required to submit monthly heartwood purchase registers within 14 days of the month in which the sandalwood was purchased during the sandalwood harvesting season. This would allow the Forest Department to calculate royalties owed (20vt/kg for processed and 40vt/kg unprocessed heartwood) owed and estimate annual harvest volumes. The log register book is supplied at cost to the license holders by the Forest Department and every purchase receipt needs to be recorded. Such a detailed log register would allow for quantification of harvest volumes from different islands, regions and possibly areas.

A 10-year license was issued to Far North Timber Sales (FNTS) for 40 tonnes of de-sapped sandalwood annually. Annual licenses were issued to various local buyers from 1997-1999 including Charlie Navian, Wong Siz Sing and Robert Yia-Nailo. In 2000 the industry consisted of 5 licensed buyers (FNTS, Meteson, TRA, Kaluat and Errosons) with a total quota of 130 tonnes which included all islands within the Tafea province and Malekula and Santo. The total harvest volume for 2000 was 76 tonnes. While data exists for annual harvest volumes across Vanuatu (Figure 1), there is very little data for harvest volumes for each island.

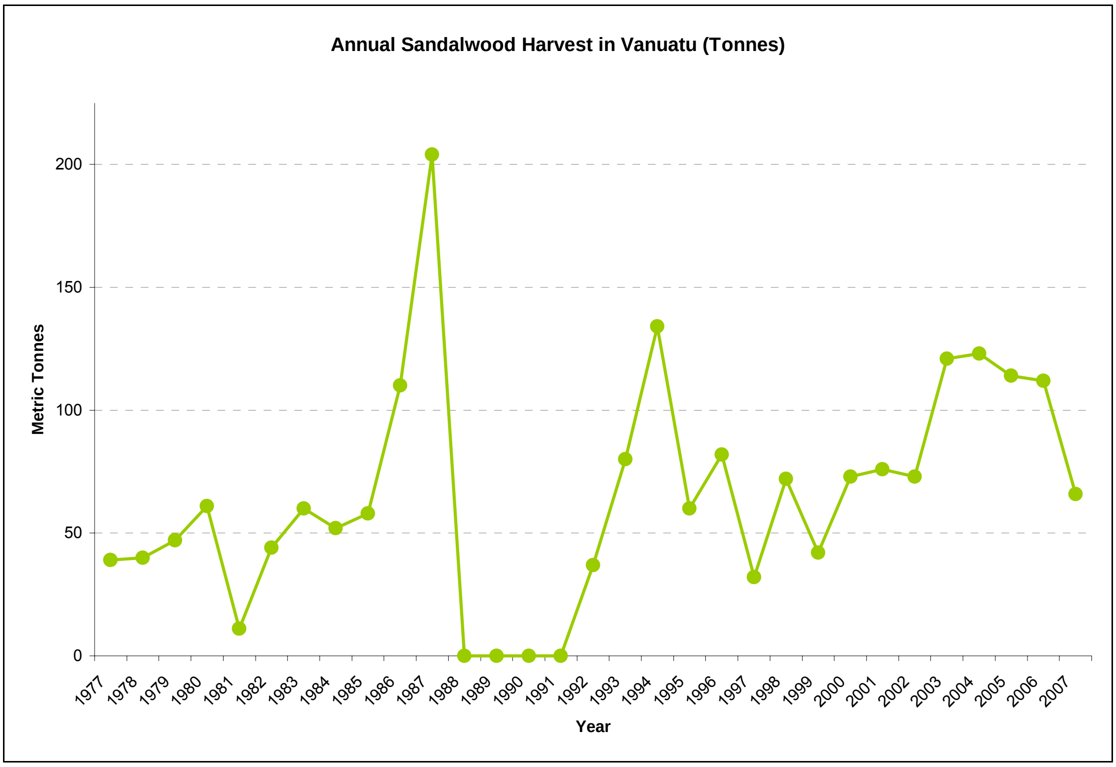

Figure 1: Volumes of heartwood harvested from wild sandalwood sources in Vanuatu

From 2001-2006 the industry comprised two buyers Far North Timber Sales (FNTS) and Tropical Rainforest Aromatics (TRA), each with an annual 40 tonne license. FNTS have purchased sandalwood from the southern islands of Erromango, Tanna, Aniwa, Futuna and Aneityum. TRA have purchased sandalwood from all islands with natural sandalwood stands (Erromango, Tanna, Aniwa, Futuna, Aneityum, Santo, Malekula, Efate and Moso).

The Sandalwood Policy (2002) proposed the establishment of a moratorium on export of unprocessed wood by 1st January 2004. These initiatives have also included the requirement for the licensee to hold a valid permit to export sandalwood before any sandalwood purchased under the license can be exported, and further stipulated the licensee should only be allowed to export oil, powder, spent biomass, and carving wood or carving. These provisions aimed to increase employment opportunities in Vanuatu, increase the value of sandalwood exports and preserve the identity of Vanuatu sandalwood as a premium product.

The Forestry Order No. 19 of 1999, banned felling of sandalwood on Efate and Aniwa for 10 years effective as of 27th May 1999, and a Forestry Order to ban felling of sandalwood on Malekula for five years was effective as of 1st June 2001. These sandalwood bans were the result of felling of small and poor quality sandalwood that did not meet market requirements. The duration of the bans was ‘based on a series of assessments on these islands’ (Mele 1999). In 2003 an unlicensed buyer began purchasing sandalwood from Aniwa and a total of 6.3 tonnes was harvested on the island. The illegally harvested sandalwood was confiscated by the Department and sold by tender; it was reported that this consignment contained some good quality trees. The Department of Forest service message for 2004 permitted the harvesting of sandalwood on Aniwa, where 25.8 tonnes were harvested. Following the maturation of the ban on Malekula 7.5 metric tonnes were harvested in 2006 and reported to contain trees with good quantities of heartwood. The Department of Forest service message for 2007 permitted the harvesting of sandalwood on Efate for the first time in eight years. A 5-tonne quota was imposed for Efate and Aniwa for 2007 and 17.7 and 4.6 tonnes respectively were harvested from these islands. Significant volumes of immature trees with little to no heartwood were harvested from Moso Island on Efate’s north-west coast. In response the Department of Forests imposed an immediate mid-season ban on harvesting trees from Moso. This shows that given accurate information, the Department has the capacity to act rapidly to limit any harvesting activities that negatively impact on the sandalwood resource.

Sandalwood is the only species to be named in the objectives of the National Forest Policy (1997) which recognizes the importance of its value to the local and national economy. Achieving the objective to "improve the management of sandalwood and encourage the development of sandalwood industries" in this Policy is supported by the regulation of cutting seasons and encouragement of local processing.

A third 10-year sandalwood license was issued to SPI Sandalwood Vanuatu in February 2005 with an annual quota of 40 tonnes. This additional license brought the annual quota to 120 tonnes of heartwood. TRA successfully challenged the issuing of this new license in court on the basis that there was no evidence that a 120 tonne quota was sustainable. Lahsaut Local Products was issued with a 2-year sandalwood license in June 2007 with a 10-tonne annual quota harvested only from Tanna. Far North Timbers' quota was reduced from 40 to 30 tonnes by the Department of Forests in 2007.

The mean annual harvest in Erromango for 2003, 04, 06 was 74.2 tonnes. In 2007 the annual harvest was 19.5 tonnes which represents a 75% reduction (Figure 3). Contributing to this reduction was the withdrawal of Buyer-Y from purchasing sandalwood 'on the beach' instead requesting landowners to ship it to their factory in Port Vila. Buyer-Y purchased an average of 28-tonnes from Erromango from 2003-2006 and in 2007 purchased 4.9 tonnes. Given that some of the Buyer-Y 'customers' would have sold their sandalwood to Buyer-X, it could be estimated that the absence of Buyer -Y constituted a 20-tonne reduction. To account for the remaining 34 tonne reduction Buyer-X proposed the following reasons of (a) Increased land disputes, (b) 50% reduction in the transport capacity of Buyer-X and (c) Increased popularity of seeds and seedlings as an alternative income.

4.3 Policy & Regulation

The 'sandalwood season' in Vanuatu operates during the drier months from June – September where cutting is permitted for three months with an additional month to allow the purchase of remaining stocks. Despite the provisions within the Forestry Act (2001) allowing the Minister for Agriculture to specify the maximum quantity of sandalwood that can be harvested in any year, VDoF has been reluctant to recommend revised quotas based on retrospective over-harvesting. Over the past 4-years the quota has been exceeded by a total of 150 tonnes, which would effectively mean that a moratorium would be imposed for 2 seasons. This shows that the industry is struggling to limit wild harvesting, and the VDoF is having difficulties regulating the annual quota.

The submission of log registers by both sandalwood licensees every month during the season, allows the Department of Forests to monitor the progressive volumes during the season and to calculate the management fee. Department records indicate that the cutting season lasted for 3 months in each of the years from 2002-2006 despite substantial over-harvesting. The delimitation of the season based on satisfaction of the annual quota, which is monitored by the submission of the monthly log registers, is a sound strategy to limit buyers exceeding their annual quota. The sandalwood harvesting season of 2007 was open from 15th July to 15th September, but it was not possible to secure the collated purchase registers for this study until December 2007. This indicates that entry and collation of the purchase registers is not rapid enough to calculate progressive harvest volumes during the season. It is feasible that monthly purchase registers for all licensees could be entered within 1-2 days, which would provide valuable information for Department Officers to determine the rate of harvesting.

Reports of poor quality and under sized sandalwood coming from Aniwa and Efate in the late 1990's led to a one year ban in 1999 (Corrigan, Naupa et al. 2000) however such reports continue from the two main sandalwood buyers in 2007. The buyers also indicate that they are concerned with the wider sustainability of the current annual quota and indicate an increase in very small and poor quality timber coming to market over the past 1-2 years. Both buyers also report that it is difficult to control the volumes of sandalwood being harvested given that it occurs in very isolated locations in the outer islands. The buyers also suggest that they are in a compromised position when they are buying sandalwood in the village and on the beach, particularly when this activity is the only genuine cash industry for villagers who can be insistent in the marketplace. To address this concern in 2007, Buyer-X has decided to only purchase product that is delivered to the processing factory in Port Vila. Buyer-X paid 1100vt/kg for approximately 14 tonnes of wood delivered from Efate/Moso (11 tonnes), Aniwa (1 tonne), Erromango (1 tonne) and Tanna (1 tonne). Buyer-X also purchased one consignment of 1.2 tonnes at South River in Erromango for 700vt/kg.

Shineberg (1967) likened the exploitation of Vanuatu sandalwood in the 1800s to that of a gold rush, given the secrecy of the extraction and the impact on the people and resource. While it is important that equitable prices are paid to the landowners for their sandalwood, the high prices now being paid and the highly competitive buying have contributed to the landowners' loss of control over their resource. Illegal sandalwood harvesting activities in Vanuatu are often a source of conflict and can result in the complete extraction of a stand. Such illegal harvesting is most pronounced in northern Erromango where there are no permanent settlements and recurrent issues over land tenure. A notable case occurred in Ponive (north Erromango) in 2006 where all trees in a demarcated reserve were harvested and exported out-of-season. This case was widely publicised because of the removal of trees with superior oil quality that were identified by the ACIAR-funded domestication project (Figure 2). While this case is important, it is not isolated and can greatly impact the long-term viability of such populations because they are often completely removed. (Michon and de Foresta 1996) reported that this type of dispossession was common in developing countries when the commercial value of traditional forest resources increases substantially.

Figure 2: Illegally harvested sandalwood within a conservation area in Ponive Erromango, which is beginning to form root suckers. We observed suckering in 2006, but there did not appear to be any substantial growth on these suckers in 2007

The declining wild resource affects the successful establishment of a planted sandalwood industry in Vanuatu in three ways (a) it can reduce market perception of the Vanuatu product as being a sustainable resource, (b) it can possibly cause a gap in supply if commercial sources are exhausted before the planted resource matures and (c) it can reduce community confidence in establishing sandalwood agroforestry. The effect on the market perception can lead to reduced prices in the marketplace for current and future sandalwood products coming out of Vanuatu which can lead to a loss in industry confidence and profitability. If the possibility of resource exhaustion is realized within the next 10-years there will be some period where no sandalwood products from Vanuatu can be traded before the planted resource, which is being established today, becomes available to the market. This would have deleterious effects on maintaining market access for the Vanuatu product. It is therefore desirable to manage the existing wild resources more effectively to ensure that the markets are maintained until the planted product becomes available.

Apart from the issue of illegal harvesting, recording and storing of harvest data may contribute to an inaccurate assessment of the total amount of sandalwood historically harvested from an area. Corrigan (2000) reported that a total of 726 tonnes of sandalwood being exported from 1977-1986 (inclusive), but the harvest data from the Vanuatu Department of Forests (VDoF) indicates this figure to be 522 tonnes. Further to this, annual harvest records can differ by up to 4-tonnes between records of the buyer and the VDoF. It has not been possible to collate detailed and accurate harvest records for the islands of Vanuatu, as this information is generally incomplete and not stored in a secure central database. These issues indicate that the current system for collection, submission, and archiving of harvest data, which are central for an accurate estimation of a sustainable annual harvest quota, is inadequate.

Based on the current 80-tonne annual harvest quota and the available data, during the period of 1993-2002, each annual harvest was on average 11% lower than the quota. In the last five years (2002-2007) however, purchase registers have recorded an average of 27% above the allowable quota. Over that period Buyer-X had purchased 8% under and Buyer-Y had purchased 71% over the quota allowed within the period.

The accuracy of the annual harvest figures have been challenged by Buyer-Y with respect to the following included in the sandalwood heartwood purchase registers.
Unclean sandalwood listed as heartwood (20-30%)
Sapwood sold as heartwood (10%)
Double counting of stolen sandalwood (10%)

The export permits for Buyer-X for 2005-2006 totalled 55.1MT of heartwood product. If a 3% oil recovery rate is assumed for the sandalwood oil listed in the export permit, then the calculated heartwood volume for this period is approximately 66.2MT. Therefore according to the Export Permits this buyer exported between 13.8 and 24.9 tonnes less than the annual purchase quota for the two year period.

Table 1: Accumulated export permits for Buyer-X for the period 2005-2006

	Volume Exported (MT)
Sandalwood Oil (100% heartwood)	1.9
Spent Charge (100% heartwood)	53.1
Waste Oil (100% heartwood)	0.1
Total	55.1

The accumulated export permits for Buyer-Y for 2001-2006 was 344 metric tonnes of heartwood (Table 2). The calculated volume of heartwood within these export permits is 241 MT which is 29 MT above the allowable purchase quota (212MT) for this period. The quota for Buyer-Y consisted of 5 years of 40 tonnes plus a special license of 12MT in 2002 for developing oil distillation techniques. According to these Export Permits over the 5 year period, Buyer-Y has purchased approximately 4 tonnes (10%) per year over the quota. This would be within an expected tolerance due to limited control of the buyer over harvesting operations carried out by landowners in the field.

Table 2: Accumulated export permits for Buyer-Y for the period 2001-2006 and the representative heartwood volumes. The relative proportions of heartwood for each product class were determined based on the buyers estimate (uncleaned heartwood) and international specifications

	Volume Exported (MT)	Heartwood Represented (MT)
Cleaned Heartwood (100% heartwood)	195	195
Uncleaned Heartwood (70% heartwood)	30	21
Sandalwood Oil (100% heartwood)	0.3	0.3
Spent Charge (100% heartwood)	18	18
Second Cutting Chips (15% heartwood)	44	7
Sap (0% heartwood)	56	0
Total	344	241

The Department of Forests can issue Certificates of Origin on request for forest products such as sandalwood that originate and are exported from Vanuatu. A total of 13 certificate entries, representing 35.5 tonnes of Vanuatu sandalwood heartwood, could not be matched with equivalent export permits. This indicates either the Export Permit data are incomplete or that the Certificate of Origin documents are issued independently of the Export Permits and may consist of a range of entries within multiple Export Permits. To improve transparency of this sensitive information, a numbered system is required for recording Export Permits which are clearly displayed on the Certificate of Origin documents. This would assist in ensuring correspondence between the two monitoring systems. Entry of all such data into a spreadsheet or database will assist the Department to rapidly identify any disparity between Purchase Registers, Export Permits and Certificates of Origin.

In the 1800s the island of Erromango was reported to have one of the most abundant and high quality sandalwood resources in Vanuatu (Shineberg, 1967). Anecdotal reports indicate that Erromango provided the bulk of the timber during the 1980s and 1990s and current figures also support this (Figure 3). Erromango provided an average of 51% of the annual harvest over a period of 6 years (1997-98, 2002-03, 2006-07) which was significantly ($P<0.05$) greater than the remaining islands. The Purchase Registers for Buyer-Y in 2003 recorded a total of 53.5 tonnes of heartwood purchased from Erromango. The largest purchases were from northern Erromango areas including Ponive (20.8MT), Punalvaad (9.2MT) and Punamalah (3.5MT) which contributed 63% of the harvest for that season. This is the only complete data set available to the study, however it confirms anecdotal reports that the northern Erromango populations have provided a significant proportion of the annual quota.

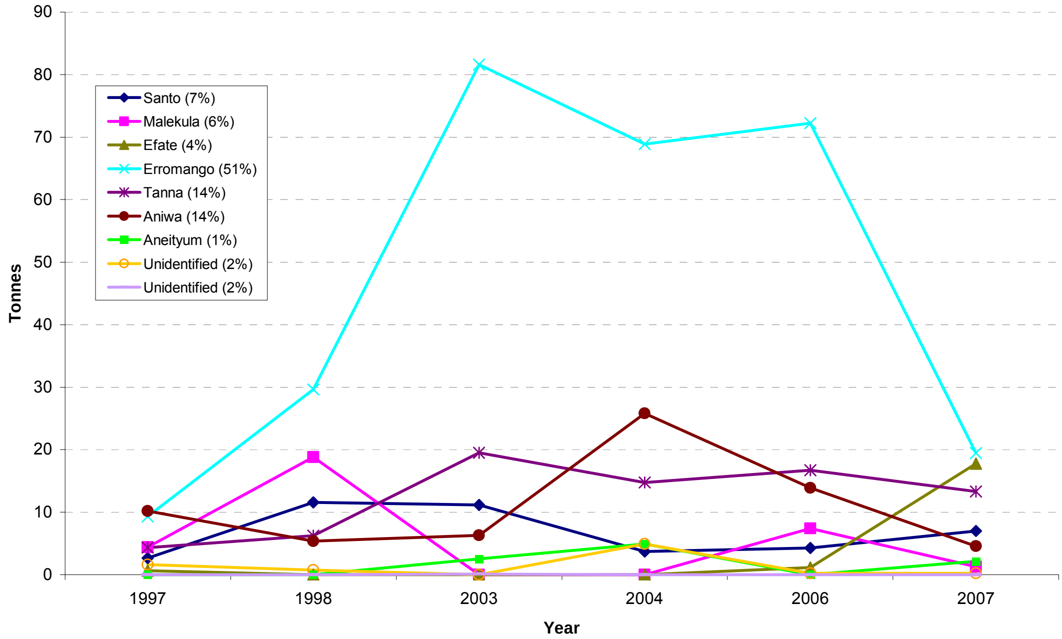

Figure 3: The proportion of annual harvest for each 'sandalwood' island in Vanuatu. Legend values in parentheses are the mean percentage for these years

In response to the increased value of sandalwood sapwood products and the needs of industry to increase the utilization of the resource, the Department of Forests has allowed the trading of sapwood during January of each year. The sapwood traded during this time was that of trees harvested during the previous sandalwood season. The administration of this new sandalwood trading activity has not kept pace with its rapid emergence in Vanuatu. Buyer-X has been trading sapwood for some time under the existing sandalwood Purchase Registers. This means that this buyer is purchasing sapwood at heartwood prices on the beach, but is only able to export it at the much reduced sapwood price. The current system imposes a financial burden on existing licensees participating in the trade of sapwood and reduces transparency in the existing sandalwood 'Purchase Registers'. It is recognised that a number of different sandalwood products exist, depending on the ratio of heartwood and sapwood (i.e. second cutting chips and unclean logs). Through industry consultation standard product specifications for Vanuatu sandalwood could be developed. To facilitate transparency only products that are included within these specifications should be listed on an Export Permit. Intermittent review of the product specifications will be required to take into account future changes in sandalwood products.

The implementation of official sapwood Purchase Registers gives the buyers an avenue for legitimately trading sapwood in Vanuatu. The value of exporting unclean sandalwood products in the international market is significantly lower than clean heartwood. Both of the main buyers have indicated that it can be difficult to refuse the purchase of unclean sandalwood on the beach. The Department of Forests has undertaken awareness activities to make it clear to landowners that all sandalwood needs to be de-sapped before selling to the licensed buyers. While such awareness programmes may assist, a much greater impact would result from license holder's refusal to purchase unacceptable sandalwood such as unclean and undersized sandalwood.

A system of two Purchase Register types for heartwood and sapwood that are associated with the respective trading season is proposed to maintain a degree of simplicity in recording and allow for comparisons between Purchase Registers and Export Permits. Any product sold with heartwood according to the Vanuatu sandalwood specifications will need to be registered in the heartwood Purchase Register. The sapwood register allows the licensees to purchase sapwood products at market prices during the sapwood trading season. To ensure a clear distinction between the two types of Purchase Registers, no heartwood (including second cutting chips) should be permitted in the sapwood Purchase Register.

While the industry is expected to record the details of sandalwood purchases and exports, it is the responsibility of the Department of Forests to administer, monitor the sandalwood industry and enforce any breaches of the Forestry Act or Sandalwood Policy. Both licensees have conveyed that very little systematic inspection of their sandalwood operations is carried out. The Department of Forests earns significant revenue from sandalwood management fees, and it is necessary that a proportion of these fees are reinvested in the industry by ensuring random and systematic inspection of operations on the beach, in the factory and on the wharf/airport. Such active involvement in the sandalwood industry by the Department of Forests will give confidence to the industry stakeholders and the international market that the resource is being managed sustainably.

5 Current distribution of the sandalwood resource

Sandalwood (*Santalum austrocaledonicum*) is restricted to the islands of Vanuatu and New Caledonia. In Vanuatu sandalwood is found on the northwest, west and southwest coasts of Erromango, the west and northwest coast of Espiritu Santo, on northern and western Tanna, Aniwa, Futuna, western Malekula, Efate and Aneityum (Figure 4). These locations correspond broadly to the drier parts of each island. The recorded altitude range is from 5m to 640m, with most occurrences at less than 200m.

Vanuatu lies in the path of the southeast trade winds, which predominate throughout the year. Between November and April these give way to short calms followed by northeasterly winds that bring rain. The northern part of the archipelago frequently experiences cyclones at this time. In the southern part of the island chain there is a greater annual temperature range and reduced rainfall. Overall rainfall varies in accordance with three main factors. First, the northern islands are significantly wetter than the southern islands. Secondly rainfall is also heavier on the higher islands than on the lower islands, and thirdly rainfall is heavier on the leeward (east and south) sides of the islands than on the relatively dry western sides. There is considerable annual variation in rainfall.

The annual rainfall associated with sandalwood is from 800–1500 mm, with some occurrences associated with a rainfall of 2500mm. Most sandalwood localities experience a pronounced dry season of 2–5 months during the cooler months from June–October. The mean maximum temperature of the hottest month is 29–33°C while the mean minimum temperature of coldest month is 16–22°C (Thomson, 2006). The minimum temperature tolerated is said to be 10–16°C.

The species grows well on a range of pure coralline soil, volcanic ash, schist or sedimentary substrates. It prefers porous, dry soils with slightly acidic to alkaline conditions and does not grow well on waterlogged soils and strongly acidic clayey soils. The trees thus prefer light to medium textured, well-drained soils (sands, sandy loams, loams, and sandy clay loams). Sandalwood prefers neutral soils (pH 6.1–7.4), but will grow in the pH range 4.0–7.4. In Vanuatu sandalwood grows on the volcanic soils of Tanna, on humic ferralitic red loams on Erromango and Efate, and on Espiritu Santo it grows on the shallow soils of raised coral terraces. When grown on red soils sandalwood develops heartwood early but does not reach a large size; on black soils it may attain greater heights but is slow to develop heartwood. Table 3 lists soil types found in the sandalwood regions of Vanuatu (Bellamy 1993).

Table 3. Sandalwood region soil descriptions taken from the VANRIS Handbook (Bellamy 1993)

Name	Description
Hydraquents	Permanently saturated, undifferentiated soils which are soft underfoot and mainly fine textured
Tropopsamments	Well to imperfectly drained undifferentiated sandy soils
Ustipsamments	Well to imperfectly drained undifferentiated sandy soils subject to seasonal moisture stress
Tropofluvents	Mainly well drained undifferentiated soils with (>0.2%) or fluctuating org C to >1 25 cm
Ustifluvents	Mainly-well drained undifferentiated soils subject to seasonal moisture stress and var org C with depth
Troporthents	Undifferentiated, mostly shallow soils typically found in wet climates on moderate to steep slopes
Ustorthents	Undifferentiated, mostly shallow soils which are subject to seasonal moisture stress
Hydrandepts	Well drained moderately weathered ash soils having irreversibly dehydrating clays and dark topsoils
Eutrandepts	Slightly weathered ash soils with high (>50%) subsoil BS values and thick black topsoils
Dystrandepts	Moderately weathered ash soils with low (<50%) subsoil BS values and thick black topsoils
Vitrandepts	Slightly weathered ash soils having dominantly sandy or gravel textures and black topsoils
Humitropepts	Moderately weathered soils having high org carbon contents (>1 2 kg/sq m) and low subsoil BS values
Ustropepts	Slightly to moderately weathered, mostly shallow (< 1 m) soils subject to seasonal moisture stress
Eutropepts	Slightly to moderately weathered soils with an altered B horizon and high (>50%) subsoil BS values
Dystropepts	Moderately weathered soils with altered B horizons and low (<50%) subsoil base saturation values
Chromusterts	Brownish clay soils found in seasonal climates with cracks remaining open 90 cumulative days or more
Pellusterts	Dark clay soils found in seasonal climates having cracks remaining open 90 cumulative days or more
Rendolls	Shallow, dark, weakly acid to neutral soils formed on calcareous parent materials
Argiustolls	Weakly acid to alkaline soils of dry climates with thick dark topsoils and finer textured subsoils
Haplustolls	Weakly acid to alkaline soils with thick, dark topsoils and subject to seasonal moisture stress
Argiudolls	Weakly acid to alkaline soils with thick dark topsoils and finer textured subsoils
Hapludolls	Weakly acid to alkaline soils with thick dark topsoils and high (>50%) base saturation levels
Haplustaffs	Moderately weathered soils subject to seasonal moisture stress and finer textured subsoils
Hapludalfs	Well to imperfectly drained, moderately weathered soils with finer textured subsoils
Hapludults	Strongly weathered, well to imperfectly drained, acid soils with finer textured subsoils
Kanhapludults	Strongly weathered, well to imperfectly drained, acid soils with finer textured subsoils and low CEC
Kanhapiustults	Strongly weathered, well-drained, acid soils subject to seasonal moisture stress with finer textured subsoils and very low CEC

Sandalwood parasitises the roots of a range of tree species and thus has specific associations with host plants. It is most common in association with *Acacia spirorbis* (namariu) in low open forest and forms part of the understorey. It is also associated with *Leucaena leucocephala*, *Cryptocarya turbinata, Hibiscus tiliaceus*, *Dracontomelon vitiensis*, *Garuga floribunda* and *Pterocarpus indicus*.

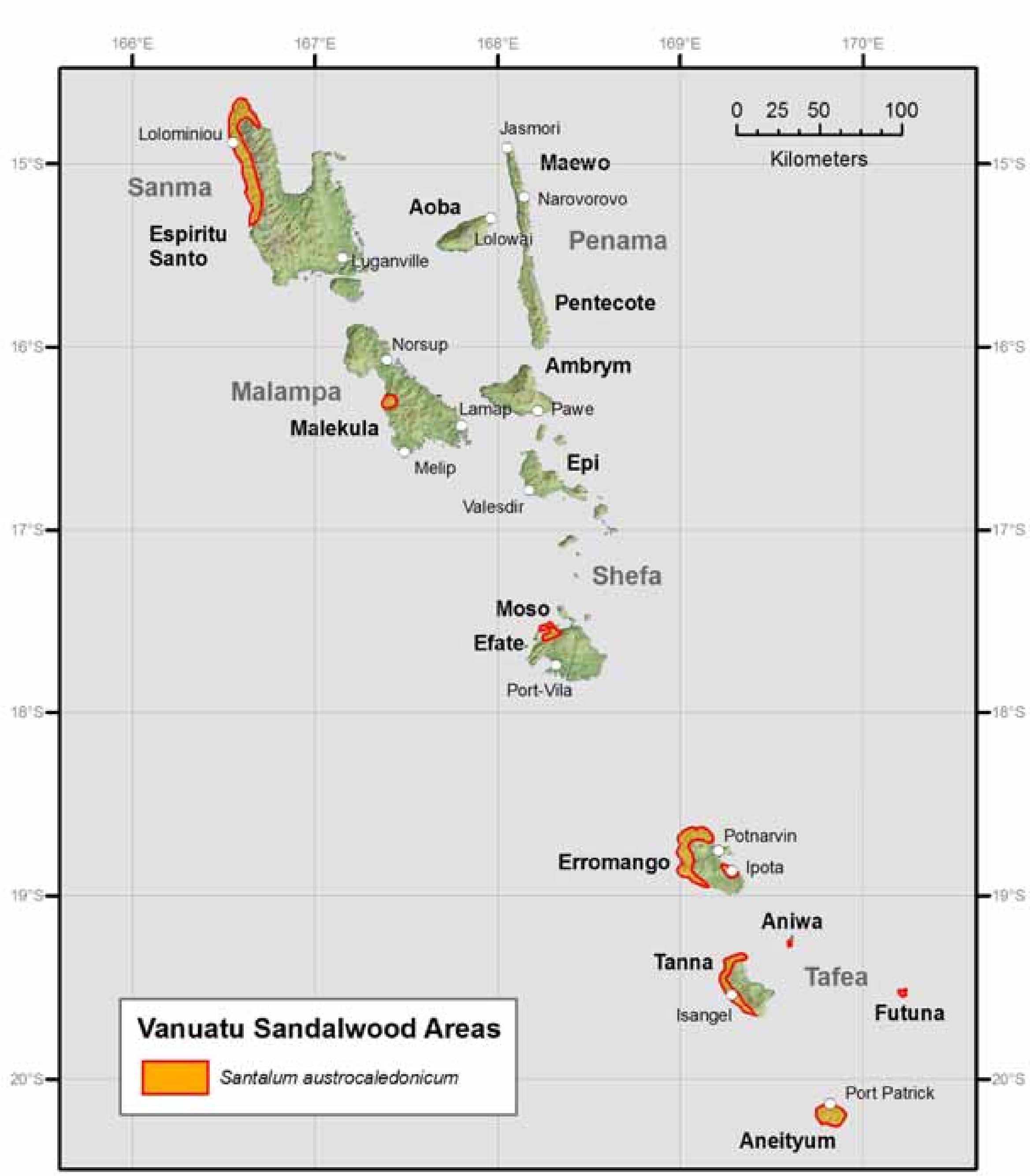

Figure 4: Distribution of Santalum austrocaledonicum in Vanuatu. Sandalwood areas were digitized from a map received from the Vanuatu Forestry Department (VDOF) (Corrigan 2000)

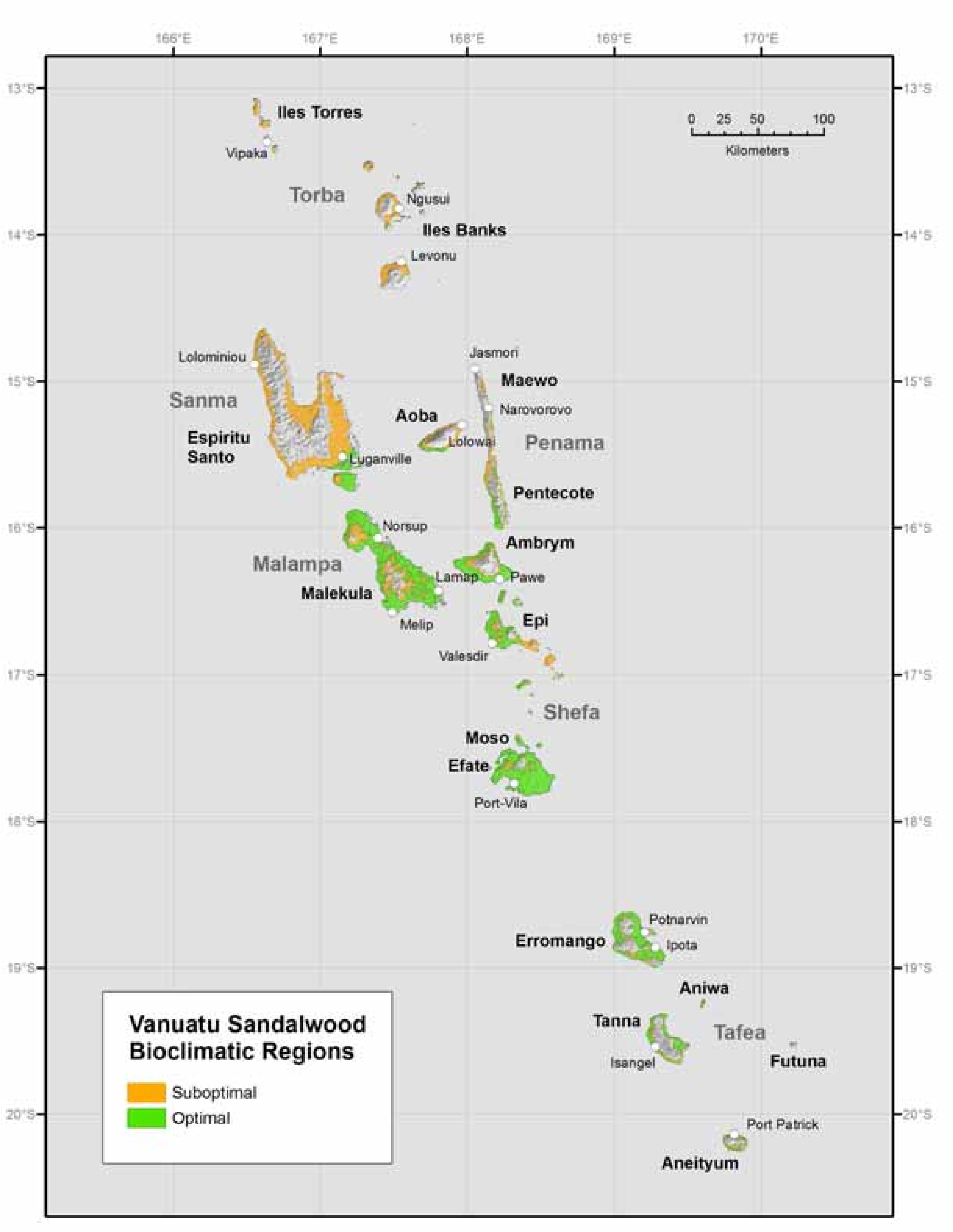

Figure 5: Potential establishment and growth of sandalwood based on bioclimatic suitability for all islands of Vanuatu

5.1 Modelling of *Santalum austrocaledonicum* distribution in Vanuatu

A focused delineation of potential sandalwood habitat was constructed both for evaluating existing wild sandalwood areas and for determining suitable habitat for cultivation. The spatial analysis methodology was based on three principal datasets:

- a bioclimatic surface where a variety of climatic parameters from BIOCLIM were matched with either the known climatic tolerances of sandalwood (Thompson, 2006) or point values extracted from the actual field survey sites
- a subset of the VANRIS resource management units of most relevance to sandalwood
- a non-forest exclusion layer based on digital classification of LANDSAT and Quickbird satellite imagery.

The climate surfaces used in the analysis were sourced from WORLDCLIM (Hijmans et al., 2005); they had a spatial resolution of 30 arc sec (often referred to as 1km spatial resolution). This is currently the best available coverage globally and regionally. The poor distribution of meteorological stations within the region makes a finer interpolation impossible. The data used were annual precipitation and mean, minimum, and maximum temperature. Input data were gathered from a variety of sources and, where possible, were restricted to records from the 1950–2000 periods. They used the thin-plate smoothing spline algorithm implemented in the ANUSPLIN package for interpolation, using latitude, longitude, and elevation as independent variables. Two approaches were taken to determine the climatic envelope of sandalwood within the climate layers. First, the climatic ranges (annual mean temperature and precipitation, temperature of coldest month, temperature of warmest month; Thomson, 2006) were used to locate optimal climatic regions for sandalwood. Secondly, BIOCLIM variables were extracted for the field locations of measured sandalwood trees (n=245, yielding 47 raster cell locations due to the coarse resolution). The mean and one standard deviation ranges of the climatic parameters were used to spatially delineate optimal sandalwood habitat (Figure 5). The Thomson estimate of suitable climate was used in preference to the field locations due to the small sample size of the latter.

Table 4: Comparison of published sandalwood climatic range with values extracted from field locations in survey

Parameter	Thomson Range		Bioclim Range	
	Low	High	Low	High
BIO6 = Min Temperature of Coldest Month (degrees)	16	22	17	19
BIO5 = Max Temperature of Warmest Month (degrees)	29	33	29	30
BIO1 = Annual Mean Temperature (degrees)	23	27	23	24
BIO12 = Annual Precipitation (mm)	800	2500	1380	2740

The Vanuatu Resource Information System (VANRIS) dataset is a part of the Vanuatu Forest Resource Survey Project contracted in 1990 by the Australian International Development Assistance Bureau (AIDAB) and implemented by the Queensland Forest Service (QFS) and the Commonwealth Scientific and Industrial Research Organisation Australia (CSIRO) (Bellamy 1993). The dataset integrates land use and vegetation communities, as interpreted from aerial photography, with geology, elevation and climate data to produce natural land units of shared physical qualities called Regional Management Units (RMUs). Out of a total 5806 RMUs created for Vanuatu, 1020 have been identified as potential sandalwood habitat based on local knowledge and ecological parameters of elevation, soil and vegetation communities. The dataset, as received from the Vanuatu Forestry Department, does not contain the disaggregated source data layers used to produce the RMUs.

The potential *Santalum austrocaledonicum* distribution was produced using digitized polygons from maps produced by Vanuatu Forestry (Figure 4) and the VANRIS regional management units (RMUs). Initially all RMUs with centre points contained within a 500m buffer of the digitized distribution polygons were selected. An iterative subtractive process was then applied removing RMUs with criteria not matching suitable sandalwood habitat. Subtraction parameters included elevation, vegetation communities and soil type. Subtracted polygons were checked against ground truth point locations of *S. austrocaledonicum.* Soil and vegetation figures for each of the individual island reports below show the resulting selected set of RMU polygons (Appendix 1).

A multispectral analysis of LANDSAT and merged Quickbird imagery used maximum likelihood classifications to establish broad land cover categories for the surveyed islands. The image data were first radiometrically corrected and then mosaiced to provide complete coverage of sandalwood regions of the surveyed islands, with the Quickbird high-resolution data covering the field transect areas. Five spectral classes were identified and related to dominant land cover types. We were unable to classify vegetation cover under areas of cloud and deep shadow. The classified images were next filtered using a 3x3 Laplacian majority filter to remove outlying single pixels, thus consolidating the classified regions. Finally the image was reduced to a single class of 'excluded vegetation' and then converted to a vector shapefile for use in ArcGIS.

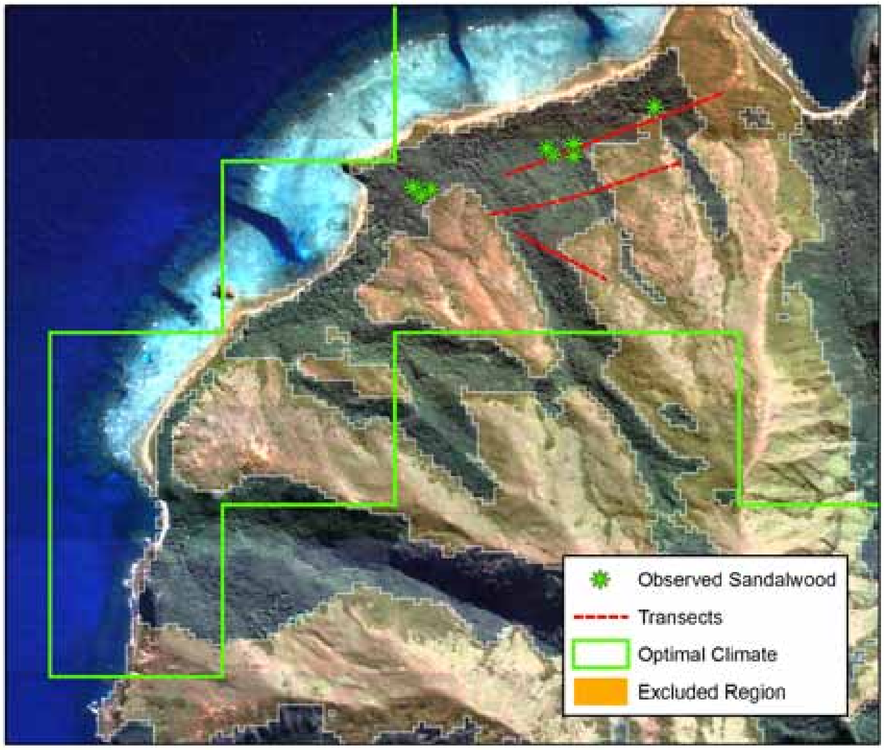

Figure 6: Example of spatial analysis for potential sandalwood growth regions. Suitability parameters to be combined were taken from bioclimatic optimum, appropriate VANRIS zone and the exclusion of non-forest vegetation regions

The optimal climate polygons were clipped to the extents of the VANRIS sandalwood region polygons in ArcGIS. These more restricted areas were then further reduced by the extents of the exclusion zones based on the multispectral classification. This produced the final suitable sandalwood regions used with the transect data for estimating sandalwood densities on individual islands.

5.2 Individual Island Descriptions

Four Vanuatu islands were surveyed for the 2007 Sandalwood Inventory: Malekula, Moso, Erromango and Aneityum (listed from north to south). Brief physical descriptions of these islands are provided below, together with a detailed sandalwood suitability map, associated vegetation and field transect maps.

5.2.1 Malekula

Malekula is formed of Miocene marine tuffs and limestones, with some andesitic lava in limited areas. The northwest part of the island and some areas on the east coast are overlain by recent coralline limestone up to an altitude of 300m. The older rocks have been eroded to form a complex of low ranges with gently rounded profiles. The highest peak, Mount Penot, attains a height of 890m. Thick alluvial deposits have been washed into the intervening valleys. In the northwest of the island the recent coral terraces have produced an undulating landscape with low, flat-topped hills. The valley of the Pangkumu River has extensive swamps.

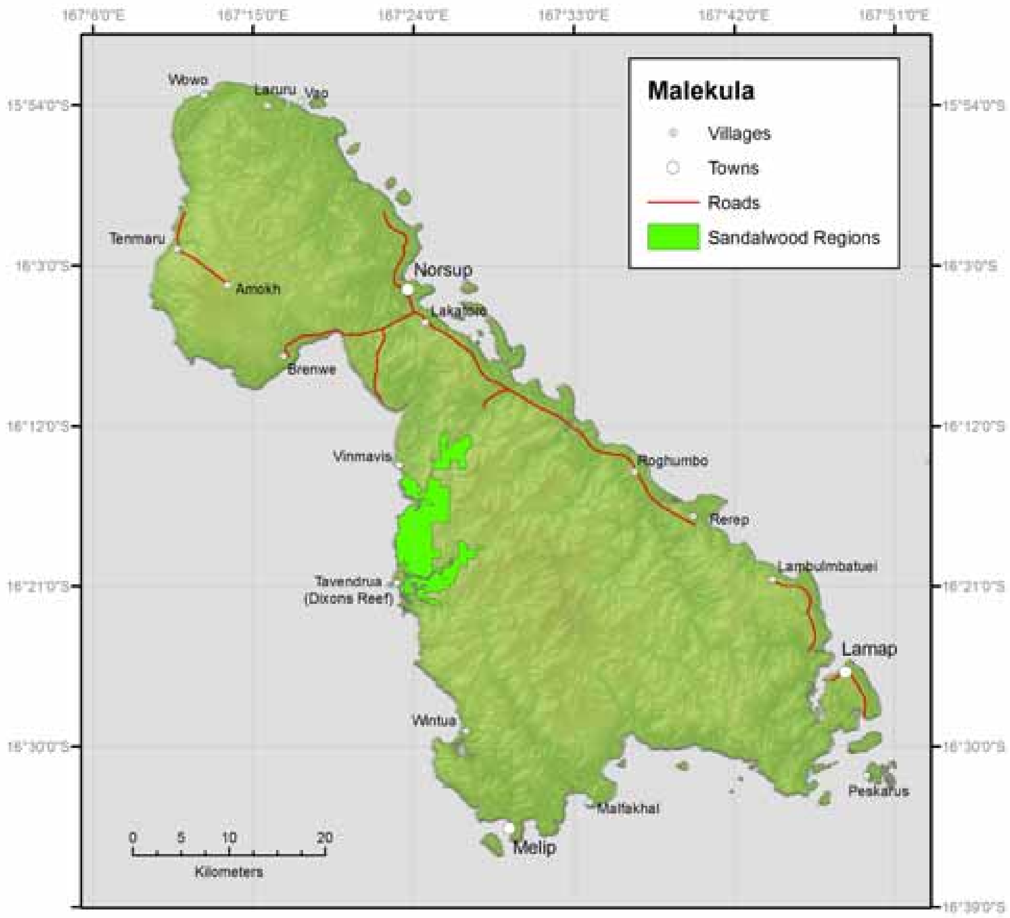

Figure 7: Map of Malekula showing potential distribution of sandalwood growth regions based on spatial analysis. Background topographic data from SRTM digital elevation model (NASA)

Table 5. Species found in association with sandalwood on Malekula transects

Acacia spirorbis	*Glochidion ramiflorum*
Acalypha grandis	*Gyrocarpus americanus*
Adenanthera pavonina	*Intsia bijuga*
Aglaia sp.	*Kleinhovia hospita*
Anthocarapa nitidula	*Leucaena leucocephala*
Bambusa vulgaris	*Macaranga tannarius*
Canaga odorata	*Mimusops elengi*
Castanospermum australe	*Murraya paniculata*
Cleidion speciflorum	*Myristica fatua*
Cryptocaria turbinata	*Pisonia umbellifera*
Cycas seemannii	*Planchonella halfordia*
Diospyros samoensis	*Pleigenium timorensis*
Dracontomelon vitiense	*Pongamia pinnata*
Dysoxylum amooroides	*Psychotria forsteriana*
Dysoxylum aneityensis	*Pterocarpus indicus*
Elaeocarpus equisetifolia	*Red Namatal*
Erynthrina sp.	*Syzygium clusifolium*
Ficus obliqua	*Tarenna efatensis*
Garuga floribunda	*Veitchia winin*

The region surveyed in Malekula lies on steep ridges above a narrow river flood plain containing a mix of low forest and bamboo. It should be noted that sandalwood only occurs in small clusters along the transects (Figure 8). The transects were designed to sample the range of topography in the area and were placed to intersect known populations of sandalwood.

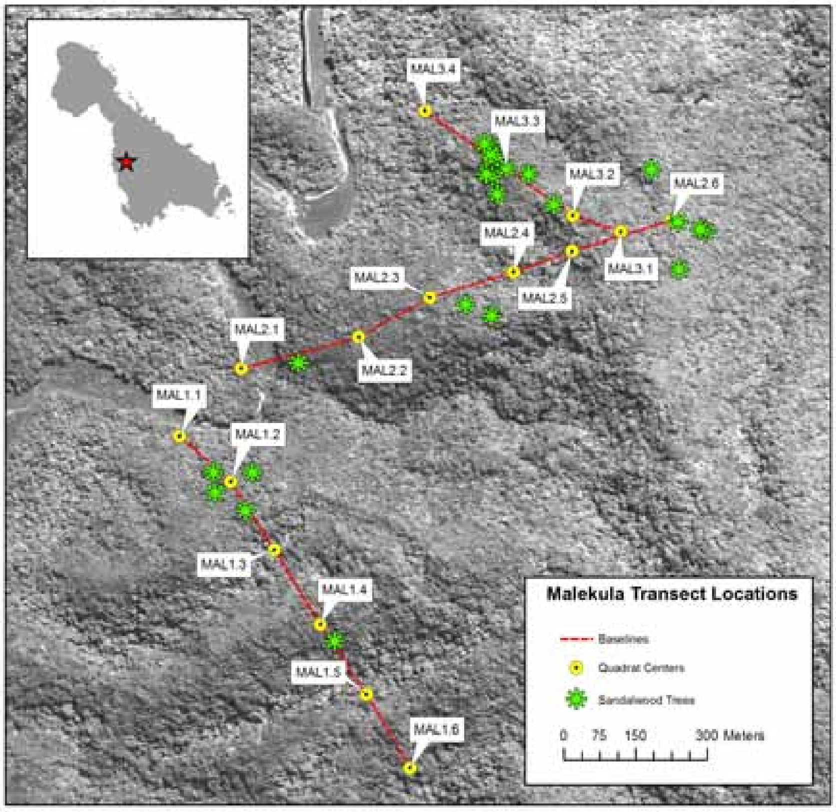

Figure 8: Malekula sandalwood transect locations and tree distribution. Transects shown over 0.6m resolution panchromatic Quickbird imagery

5.2.2 Efate and Moso

Efate is of volcanic origin but is almost completely encrusted with coralline limestone. In the north are beds of coarse agglomerate overlain by pumice and soapstone. Later volcanic activity has penetrated these beds with intrusive andesite and basalt lavas. The island of Moso, off the northwest coast, has a foundation of soapstone overlain by coralline limestone. The central ridge of the island, in the north, is dissected and attains a height of 670m. The southern part of the island is a plateau 60-100m high, intersected by coral ridges dipping to the southeast.

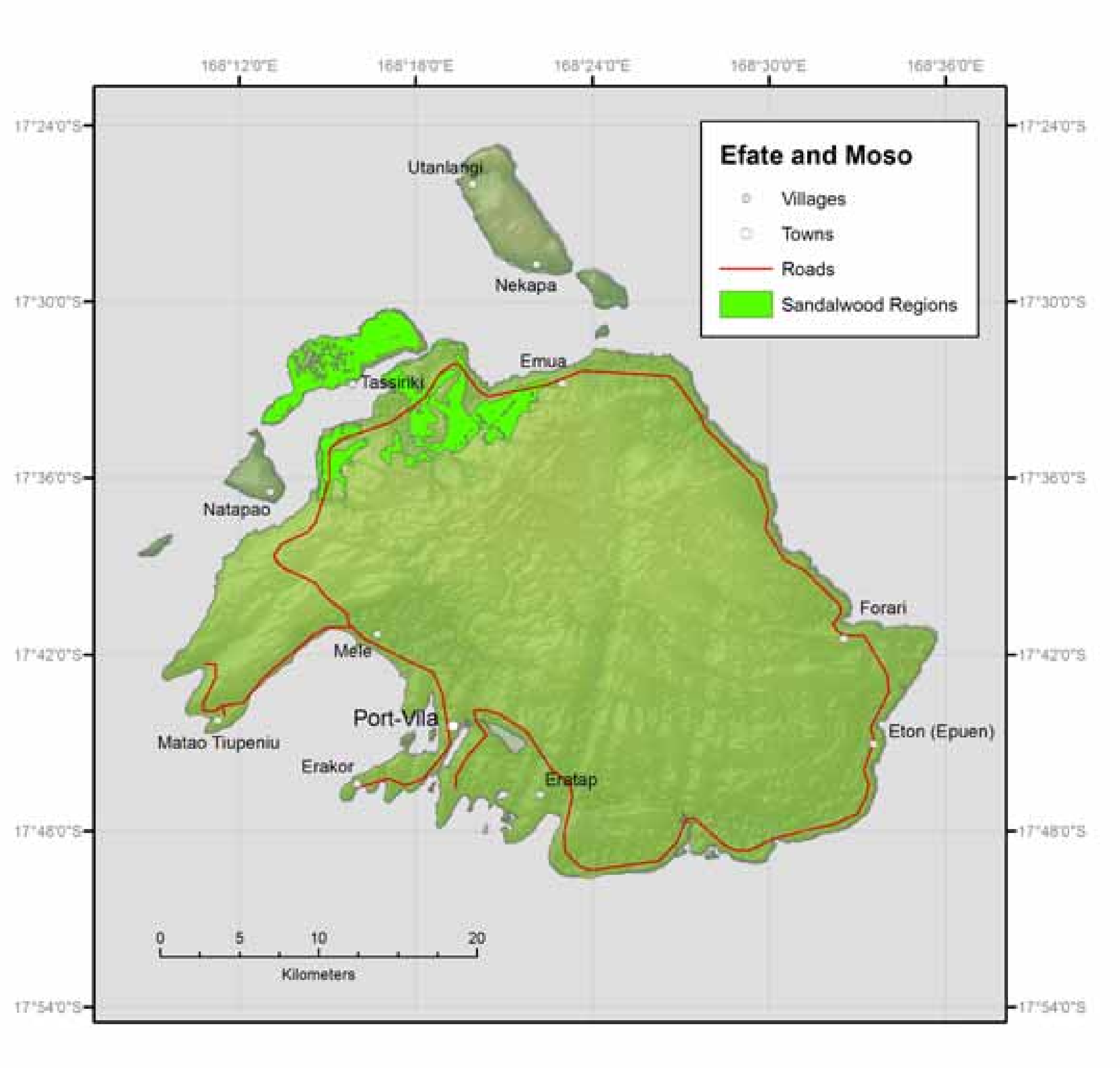

Figure 9: Map of Efate and Moso showing potential distribution of sandalwood growth regions based on spatial analysis. Background topographic data from SRTM digital elevation model (NASA)

Sandalwood occurs in low to midheight open canopy forests in the dry region of northwest Efate and Moso Island. It has also been observed to grow among thickets dominated by Leucaena and Acacia spriorbis and along grassland margins. Table 6 provides a list of species observed while conducting the survey. Not all species listed are confirmed.

Table 6. Species found in association with sandalwood on Moso transects

Acacia spirorbis	*Leucaena leucocephala*
Adenanthera pavonina	*Mimusops elengi*
Aglaia elagnoides	*Murraya paniculata*
Aglaia saltatovum	*Pouteria costata*
Aglaia sp.	Pouteria sp.
Celtis paniculata	*Psychotria forsteriana*
Celtis sp.	*Psychotria fosteriana*
Croton insulare	Psychotria sp.
Cupaniopsis aneityensis	*Pteorocapus indicus*
Elattostachys falcata	*Rivina humilis*
Ervatamia obtusciuscula	*Rivinia humilis*
Eugenia sp.	*Tarenna efatensis*
Gyrocarpus americanus	*Tebernai montanna*

The region surveyed in Moso contained lightly rising slopes in mixed forest and thickets. Sandalwood generally occurred in small clusters on the transects (Figure 15). The transects were designed to sample the range of topography in the area and were placed to intersect known populations of sandalwood.

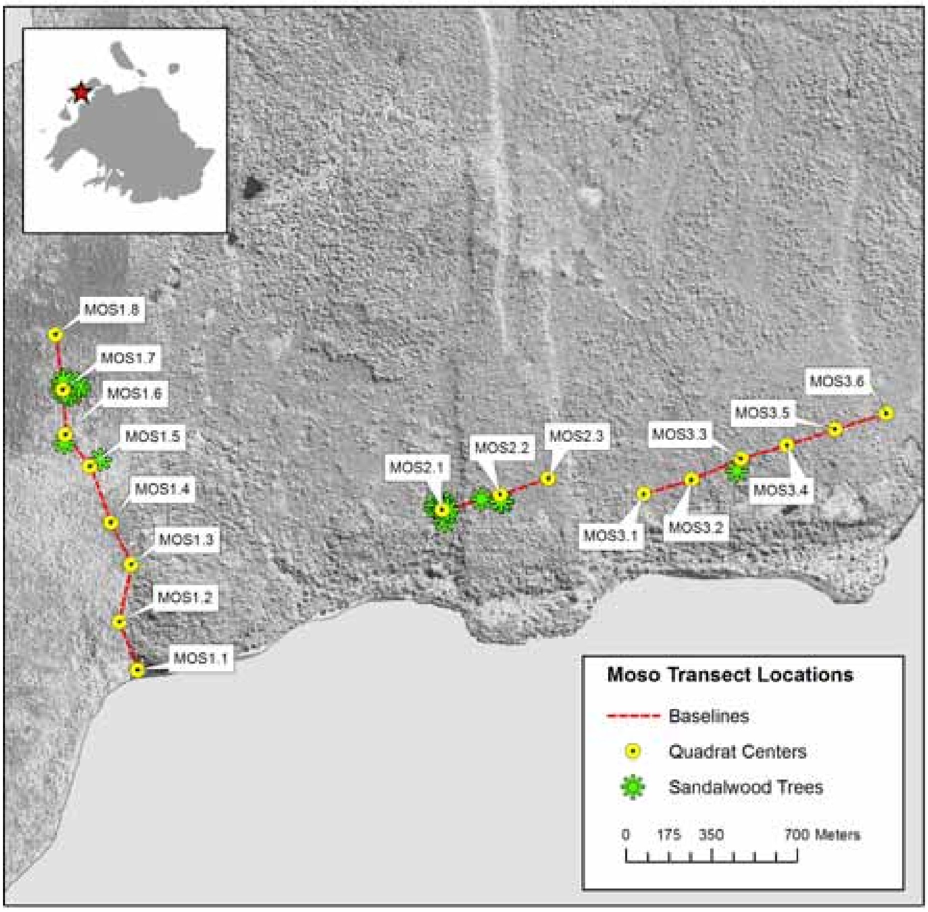

Figure 10: Moso sandalwood transect locations and tree distribution. Transects shown over 0.6m resolution panchromatic Quickbird imagery

5.2.3 Erromango

Erromango is the largest of the southern islands of Vanuatu and is composed mostly of lavas and volcanic agglomerates. Raised coral terraces attain heights up to 250m. The central mountain chains run north-south and east-west in the south and are up to 900m high. The southeastern side of the island is forested and well watered. The western side of the island experiences droughts and supports extensive grasslands.

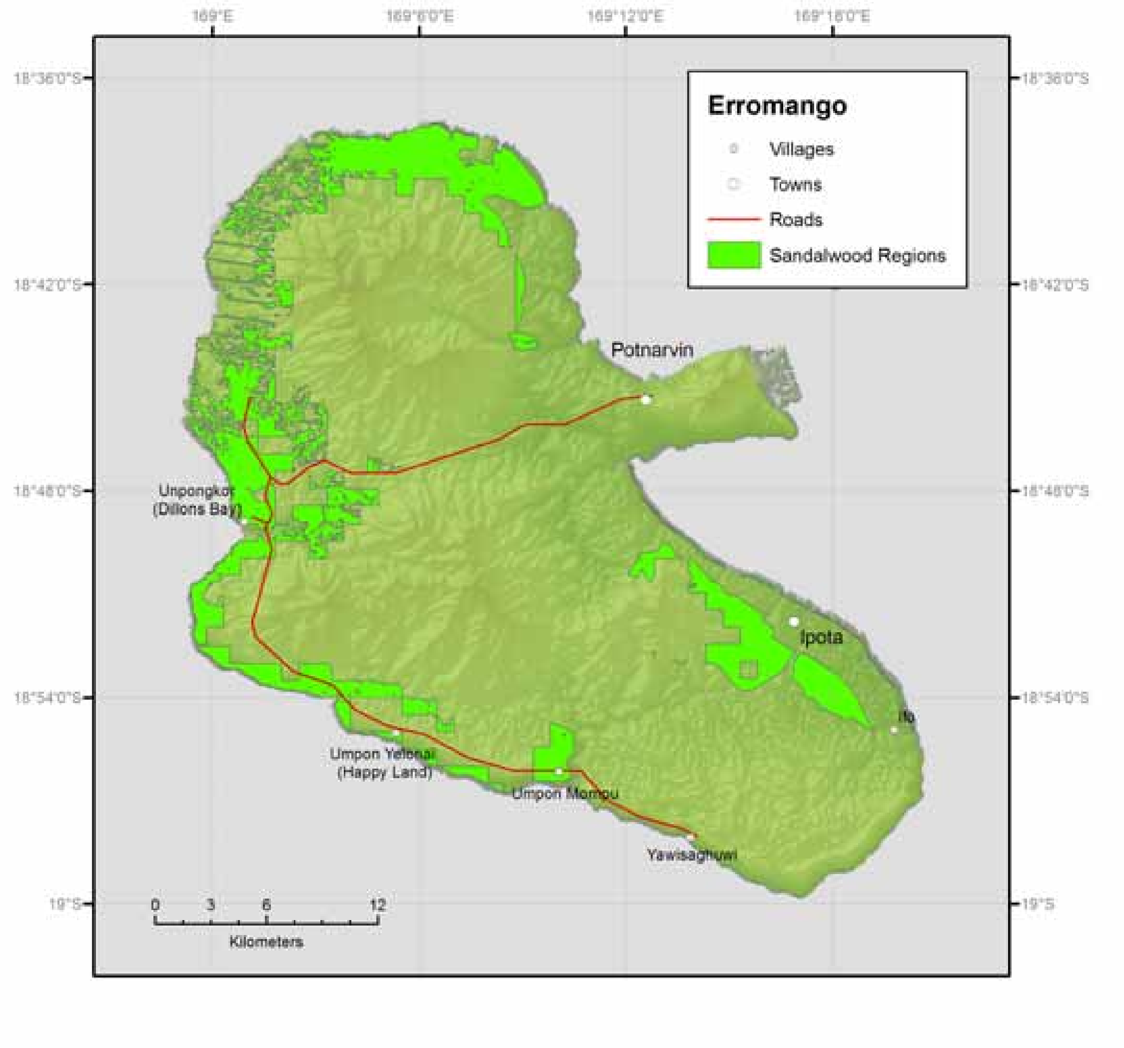

Figure 11: Map of Erromango showing potential distribution of sandalwood growth regions based on spatial analysis. Striping in northwest regions due to line dropout in Landsat imagery used in spatial analysis. Background topographic data from SRTM digital elevation model (NASA)

The sandalwood regions of Erromango typically contain low to midheight open canopy forests with populations of *Casuarina equisetifolia* and *Acacia sprirorbis*. Sandalwood is also associated with *Leucaena* thicket, grassland and herbaceous communities along forest margins. Table 7 provides a list of species observed during the 2007 sandalwood survey. Not all species listed are confirmed.

Table 7. Plant species found in association with sandalwood on Erromango transects

Acacia spirorbis	*Elattostachys falcata*	*Murraya paniculata*
Acalaia sp.	Ervatamia sp.	*Orchrosia manghas*
Adenanthera pavonina	*Evodia hortensis*	Pandanus sp.
Aleurites moluccana	*Ficus adenospermum*	*Pleigenium timorensis*
Alphitonia ziziphoides	*Ficus obliqua*	Polyscias sp.
Annona sp.	*Ficus wassa*	*Pometia pinnata*
Artocarpus altilis	Garcinia sp.	*Pongamia pinnata*
Bischoffia javanica	*Gardenia tannaensis*	*Psychotria forsteriana*
Christella sp.	*Garuga floribunda*	Psychotria sp.

Citrus sp.	Glochidion sp.	*Pterocarpus indicus*
Cocos nucifera	*Gyrocarpus americanus*	*Rivina humilis*
Commersonia bartramia	*Inocarpus fagifer*	*Selaginella durvillei*
Cryptocaria sp.	*Leucaena leucocephala*	*Semecarpus vitiensis*
Cupaniopsis aneityensis	*Macaranga dioica*	*Sterculia tannaensis*
Cupaniopsis sp.	Macaranga sp.	*Syzygium malaccensis*
Cyperaceae sp.	*Macaranga tannarius*	*Tarenna efatensis*
Dracontomelon vitiense	*Mangifera indica*	*Terminalia catappa*
Dysoxylum aneityensis	*Mimusops elengi*	*Wedelia biflora*
Elaeocarpus floridanus	*Morinda citrifolia*	

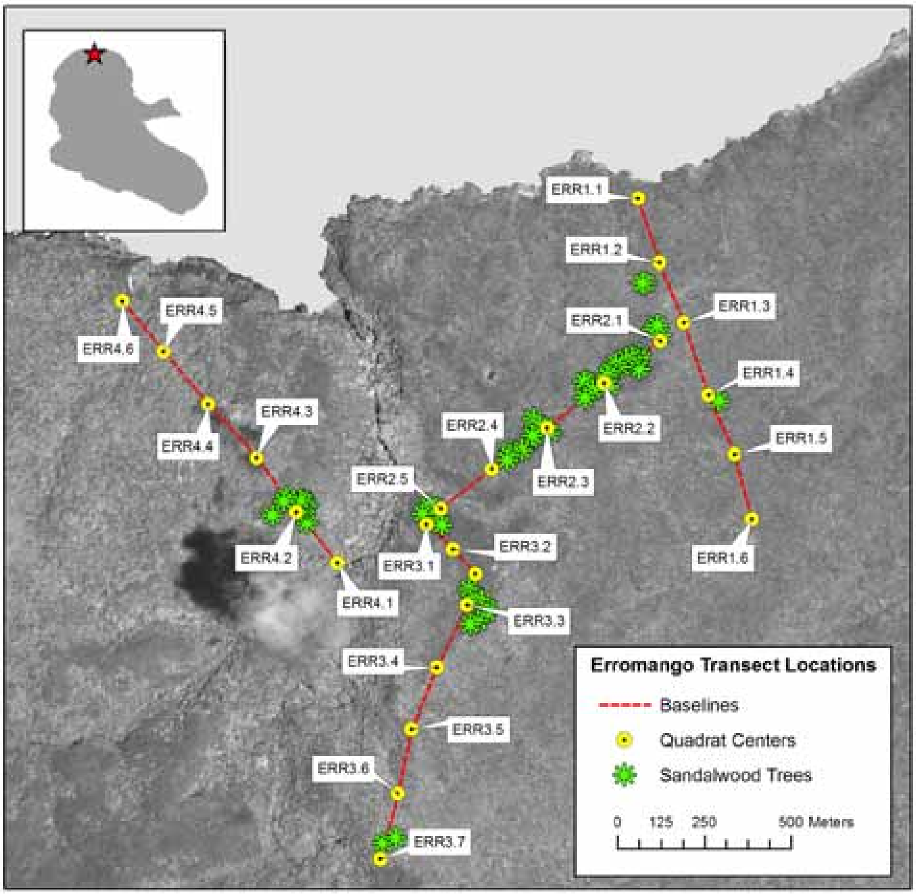

Figure 12: Erromango sandalwood transect locations and tree distribution. Transects shown over 0.6m resolution panchromatic Quickbird imagery

The Erromango transects are located on dominantly flat to undulating terrain interspersed with deep drainages cut through raised coralline limestone and older lava and agglomerate. The transects were designed to go through regions of known sandalwood and to sample the range terrain present in the area. Again sandalwood tended to occur in clusters with significant distances between them (Figure 12).

5.2.4 Aneityum

Aneityum is the southernmost island of the archipelago and is almost circular, being of volcanic origin. A high central massif rises to 850m. Buttress-like ridges radiate from it to the sea, dividing the island into deep valleys. The coast is almost entirely circled by fringing reef, and there is extensive beach rock.

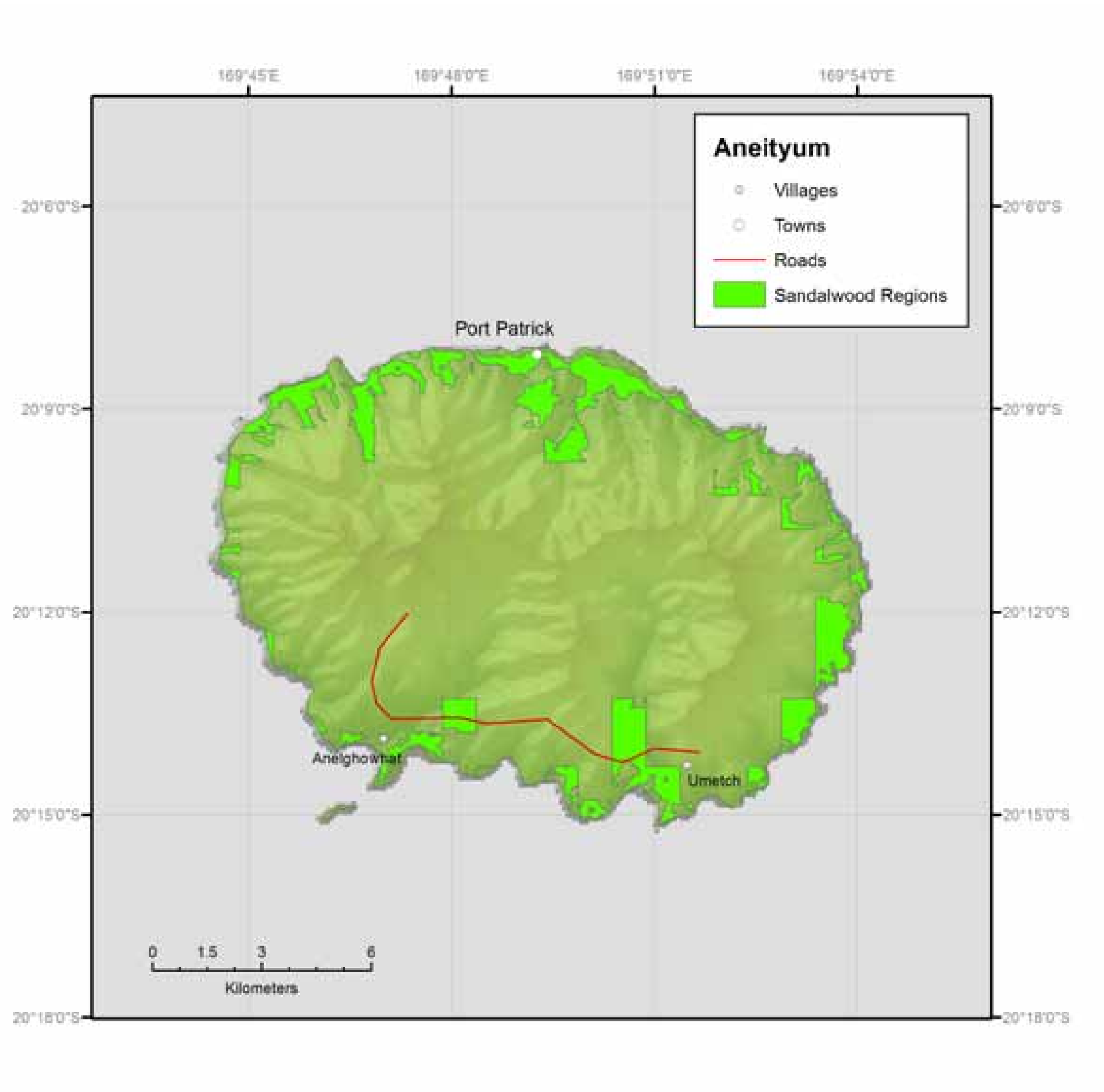

Figure 13: Map of Aneityum showing potential distribution of sandalwood growth regions based on spatial analysis. Background topographic data from SRTM digital elevation model (NASA)

Sandalwood on Aneityum is associated with low mixed species forests typically with, and sometimes dominated by *Acacia spirorbis.* Sandalwood is also associated with forest margins of thickets containing *Agathis-Calophyllum* and *Leucaena.* Table 8 provides a list of species observed during the 2007 sandalwood survey. Not all species listed are confirmed.

Table 8. Plant species found in association with sandalwood on Aneityum transects.

Leucaena leucocephala	*Metrosideros collina*
Acacia spirorbis	*Mimusops elengi*
Adenanthera pavonina	*Morinda citrifolia*
Aglaia sp.	*Murraya paniculata*
Alphitonia ziziphoides	*Orchrosia manghas*
Annona sp.	*Passiflora suberosa*
Casuarina equisetifolia	*Pittosporum aneitiensis*
Commersonia bartramia	*Pittosporum sp.*
Cyperaceae sp.	*Polyscias gracilibas*
Dianella sp.	*Polyscias guiffoles/guivilles*
Elattostachys falcata	*Polyscias sp.*
Ervatamia obtusciuscula	*Premna seratifolia*

Ficus obliqua
Ficus tinctoria
Glochidion ramiflorum
Glochidion sp.
Gyrocarpus americanus
Hibiscus tiliaceus
Leucaena leucocephala
Mangifera indica
Psidium guajava
Psychotria aneityensis
Psychotria forsteriana
Pteridium esculentum
Rivina humilis
Scaevola sinensis
Tarenna efatensis

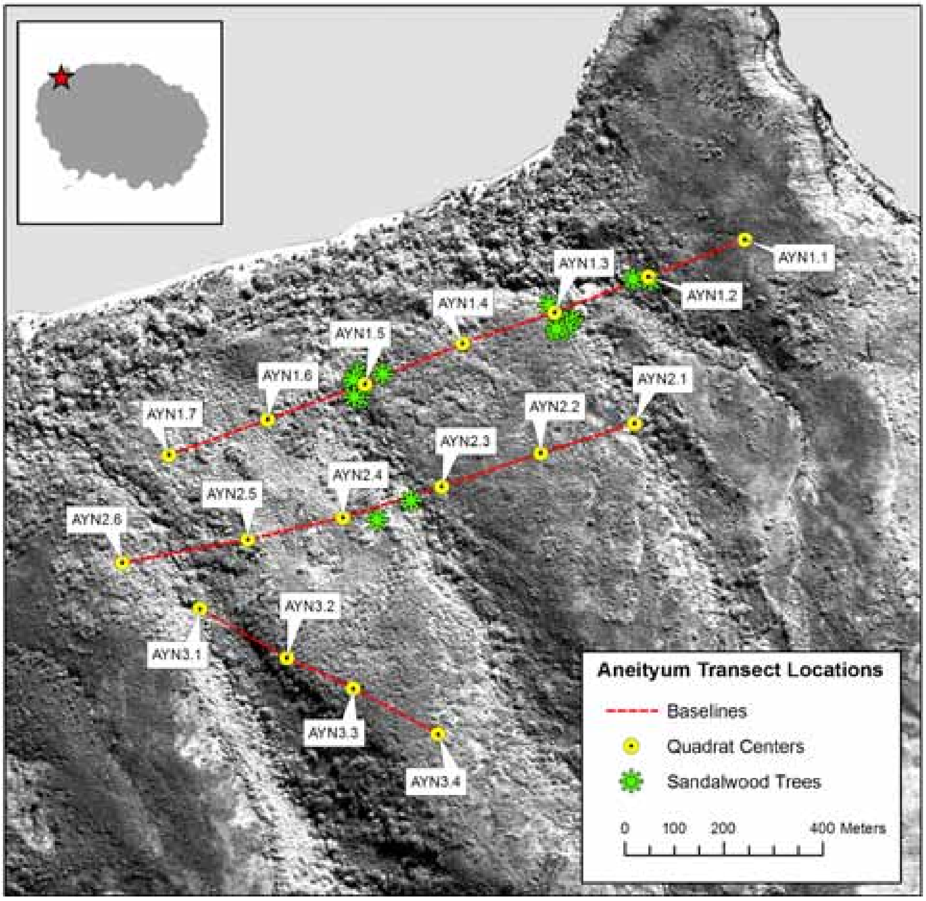

Figure 14: Aneityum sandalwood transect locations and tree distribution. Transects shown over 0.6m resolution panchromatic Quickbird imagery

The Aneityum transects (Figure 14) were located to sample a mixture of residual volcanic terrain and more recent raised coralline limestone. The transects were organized both parallel and against the contours and crossed several deeply incised drainage lines. Sandalwood was sparse in this area with well separated clusters.

6 Inventory of *Santalum austrocaledonicum* in four islands of Vanuatu

6.1 Methodology

To quantify tree numbers, size class and spatial distribution of *S. austrocaledonicum,* a field inventory was carried out in four known populations across four different islands of Vanuatu (Malekula, Moso Erromango and Aneityum). These areas were selected because they are recognised as being 'natural' populations, as opposed to planted and in the case of Erromango a significant source of commercial sandalwood. For each island the survey team was guided by local knowledge to areas of known sandalwood occurrence. For each population a field inventory was undertaken using a combination of line transect (Buckland, Anderson et al. 1993) and systematic quadrat sampling. A linear transect of a consistent bearing was followed and individual sandalwood (trees, saplings, seedlings and suckers) were identified and measured in terms of their perpendicular distance and direction from the base line and their stem diameter (at the base and breast height). Quadrats were centred at 200m intervals along the transect that measured 40m either side of, and 25m along the transect (*i.e.* 80 x 25m) and all sandalwood specimens within were located and their stem diameter measured. The main tree and understorey species and canopy gap fraction using a densiometer were recorded for each tree identified and each quadrat measured. A total of 11.7km of transects and 74 individual quadrats were surveyed across the four sites (Table 9).

Table 9: Number of transects and quadrats surveyed and total length of transects covered for each island.

Island	Number of Transects	Total Length of Transects (km)	Number of Quadrats
Malekula	3	2.5	16
Moso	3	2.8	17
Erromango	4	2.5	17
Aneityum	3	3.9	24
Total	13	11.7	74

The level of aggregation or 'tree clustering' in each of and overall the islands was tested using a variance-to-mean ratio test for clumped distribution and standardised Morisita index of dispersion (Krebs 1999). A variance-to-mean ratio of zero indicates maximum uniformity, a ratio of one indicates randomness and a ratio tending towards the total number of observations indicates maximum aggregation or clustering. The standardized Morisita index has a range from -1.0 to +1.0 with 95% confidence limits at +0.5 and -0.5. An I_p of zero indicates random, above zero indicates clumped and below zero indicates uniform distribution.

Species identified over all quadrats surveyed were recorded in a binary matrix consisting of 109 associated species and 78 individual quadrats; the presence of an associated species in a given quadrat was represented by 1 and absence by 0. Similarity between quadrats was calculated from the binary matrix using Jaccard's Coefficient (Sneath and Sokal 1973). Non-metric multidimensional scaling (NMDS) was used to represent the relative differences in species assemblages between quadrats in a reduced space while conserving, as much as possible, the similarity coefficients between each quadrat, recorded in the Jaccard similarity matrix. A random configuration of the quadrats in 2-dimensions was generated to compare the relative differences in species assemblages between quadrats with and those without sandalwood present. A configuration with a stress value of less than 0.1 is considered to be a 'good' representation of the true distances in the original data set (Kruskal 1964; Rohlf 1998).

An estimation of standing heartwood volumes per hectare for each population was undertaken using density measurements for commercially sized trees (basal diameter >15cm) from this study and a DBH vs heartwood weight regression calculated by Hook (1997).

6.2 Results

6.2.1 Tree Densities

The mean density of sandalwood over all populations was 4.6 individuals/ha. The size class distribution over the survey area was skewed towards very small seedlings/suckers (basal diameter 0.5 -2 cm) and saplings (2-15cm) (Figure 15). In Malekula only 11 sandalwood trees were located within the survey area and no seedlings/suckers (0.5-2cm) or small saplings (2-5cm) were found (Figure 16). While many more trees were located in the Moso survey area (28) than Malekula (8), no seedlings/suckers (0.5-2cm) were found. Substantially greater levels of seedlings/suckers were recorded for Erromango (2.3 stems/ha) and Aneityum (1.9 stems/ha). While the density of trees in larger diameter classes in Aneityum reduced 'gradually', in Erromango this density reduction in was abrupt with a 75% decrease to the saplings class (2-5cm).

The common feature of all populations was the consistently low mean density of commercial sized trees (basal diameter >15cm) which was 0.4 individuals/ha. No trees were found above 25cm in diameter and only 0.12 stems/ha were found for trees of 20-25cm size class (Figure 15). In the surveyed population of northern Aneityum the landowners indicated that there used to be substantial numbers of trees in the area that were harvested during the 1970's and early 1980's. With negligible harvesting for 25-30 years there are still low densities (0.4 individuals/ha) of commercially sized trees.

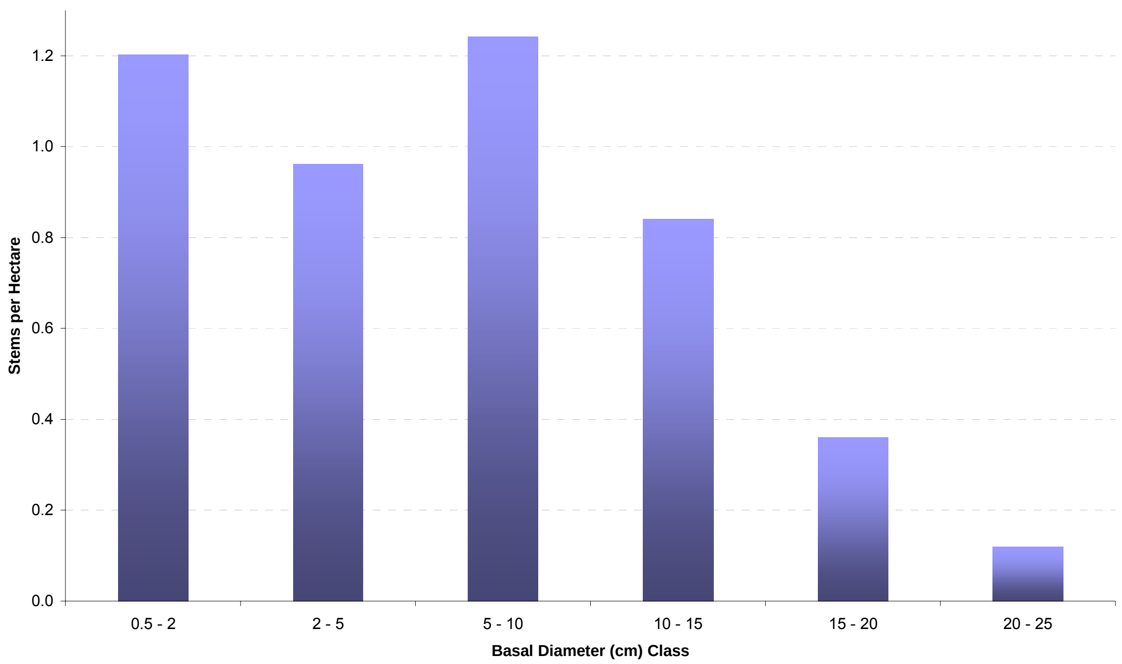

Figure 15: Density of basal-diameter size classes in natural sandalwood surveyed in Vanuatu.

The density of harvested trees identified in Erromango was 1.5 individuals/ha and it is estimated, by the limited re-growth of sucker material, that these trees were harvested within 12-24 months of this field inventory. To estimate the possible density and size classes of mature trees before harvesting, those individuals that were identified as being harvested were re-identified as mature trees in the size class proportions identified in this population during the 'Oil Quality Survey' ('15-20' = 40%, '20-25' = 23%, '>25' = 36%) (Figure 17). The number of trees representing the new size class densities were selected at random from the 'Oil Quality Survey' and a heartwood volume of 110kg/ha was estimated using the 'heartwood recovery' regression (Hook 1997), which was significantly greater than the 26.9kg of heartwood per hectare after harvesting.

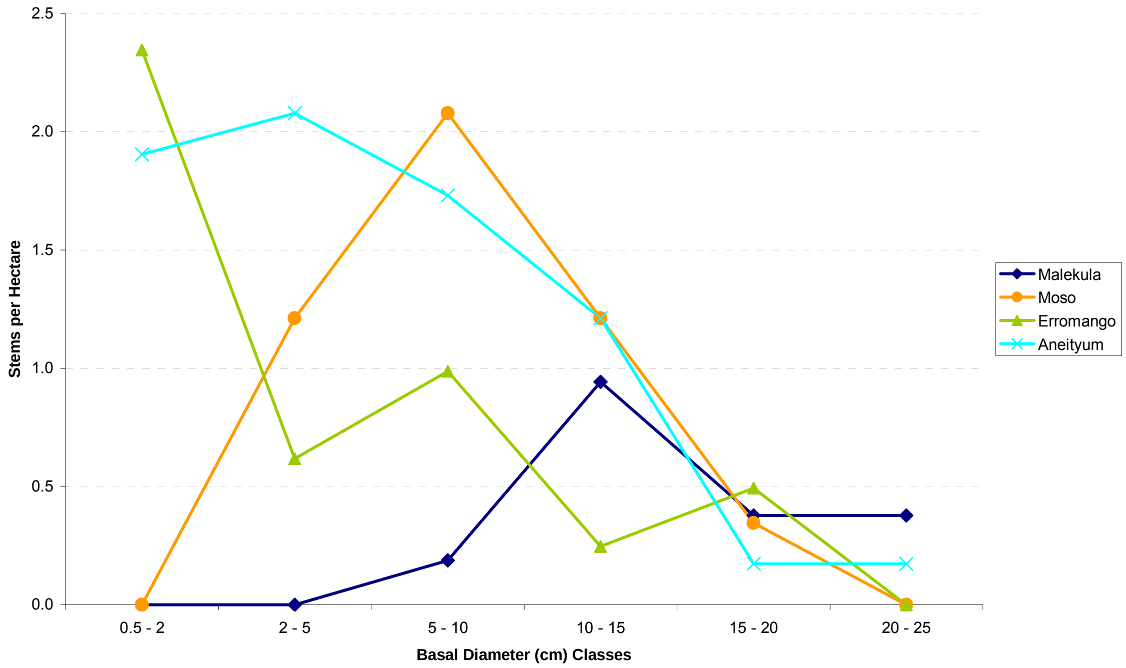

Figure 16: Density for basal-diameter size –classes in natural sandalwood surveyed in four islands (Malekula, Moso, Erromango and Aneityum) across Vanuatu.

The standardised Morisita index of dispersion (Krebs 1999) across all populations was 0.5944 and the variance to mean ratio test for clumped distribution was significant (P=0.00) for all three populations with individuals identified in the surveyed quadrats. These results indicate that the species is highly aggregated and found in clusters of individuals.

Table 10: Indices of dispersion for each population and combined all populations ('all 4 pops')

	Malekula	Moso	Erromango	Aneityum	All 4 pops
Number of quadrats	16	17	24	17	74
Mean No. Sandalwood in each quadrat	0.1875	1.4706	0.7083	2	1.027
Variance	0.5625	21.13971	3.60688	43.625	15.86227
Variance: Mean Ratio	3	14.375	5.092	21.813	15.445
Variance:Mean Ratio Test for Clumped Distribution :	0.00	0.00	0.00	0.00	0.00
Chi-Squared	67.23	230	117.118	349	1127.474
Degrees of Freedom	15	16	23	16	73
Standardized Morisita Coefficient (Ip)	1	0.771	0.612	0.8107	0.5944

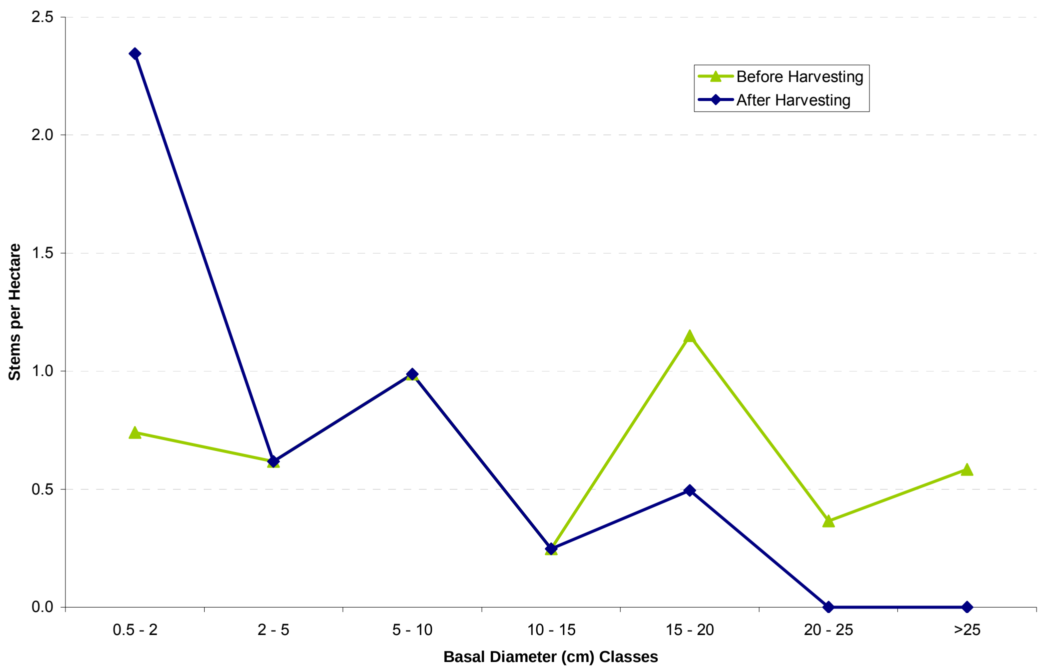

Figure 17: Densities for basal-diameter size classes before (estimated) and after recent (12-24 months) harvesting activities within the natural sandalwood surveyed in Erromango (Punalvaad)

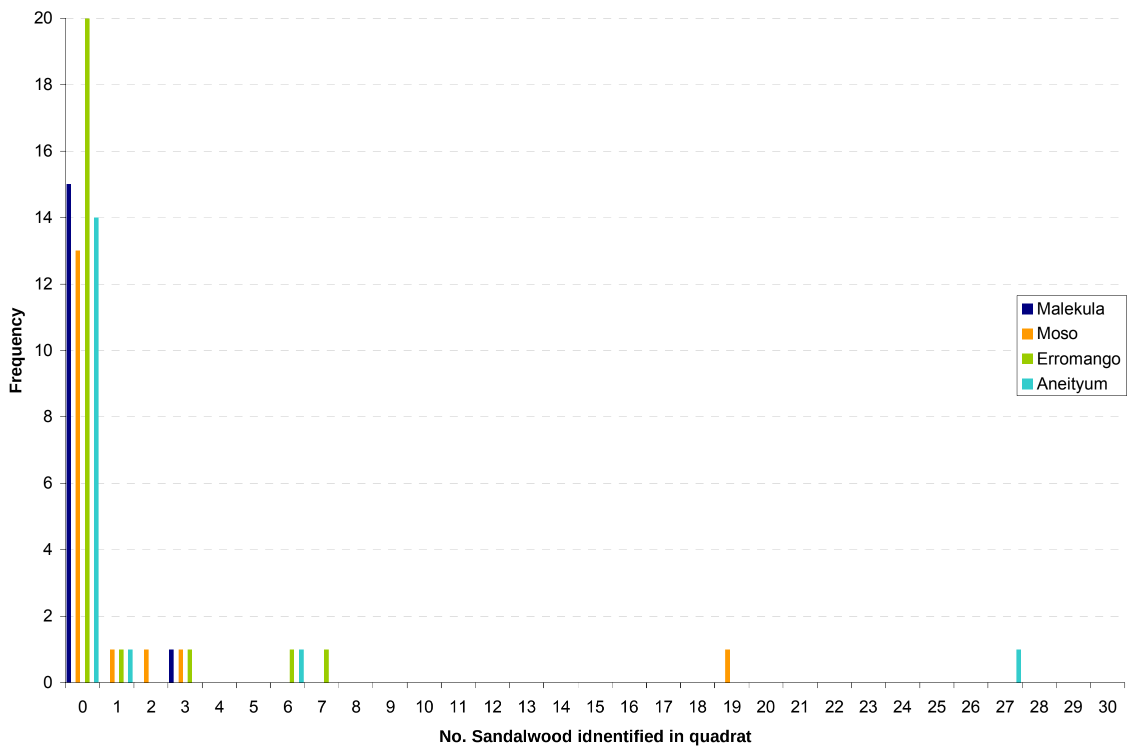

Figure 18: Frequency of recorded sandalwood in the quadrats for each island

An estimate of the total sandalwood resource on the four islands surveyed was obtained (Table 11) by combining the potential habitat area from section 5.2, the surveyed trees listed in Appendix 1, and a regression to estimate heartwood weights from DBH values developed by Hook (1997). This estimate is subject to large standard deviations given the small sample of sandalwood trees of merchantable size. The total estimated resource for all four islands is only 209 tonnes. Half of this resource is on Erromango.

Immediately following the survey in 2007, the sandalwood season was opened including Efate and Moso. Within a month of the season's opening four tonnes had been harvested from Moso, including significant volumes of undersized trees with little or no heartwood. At that point the VDoF prohibited any further harvesting on Moso Island. This would support the validity of the low estimate in Table 11 for that island.

Table 11: Estimated sandalwood resource on four islands of Vanuatu. Based on field survey data, with heartwood weight based on regression by Hook (1997)

Island	Habitat hectares	Estimated merchantable tree numbers	Estimated heartwood weight (tonnes)	Standard deviation (tonnes)
Aneityum	1756	608	10.1	6.5
Erromango	13159	6498	108.5	70
Malekula	6179	4663	77.8	50
Moso	2105	729	12.2	7.8
TOTAL	**28477**	**12499**	**208.7**	

An estimate of the likely resource in the future can be obtained by projecting the size classes from Figure 15 forwards to 6-8 years and 12-16 years from now (Figure 19). This indicates that the total projected resource on the four islands will be only approx. 0.8 stems/ha and 1.2 stems/ha respectively. These will only be small trees due to harvesting of the oldest and largest trees, and there will be an accompanying reduction of 30 to 60% in recruitment as a result of this loss. This is indicated in Figure 19 by cross hatching on the bars.

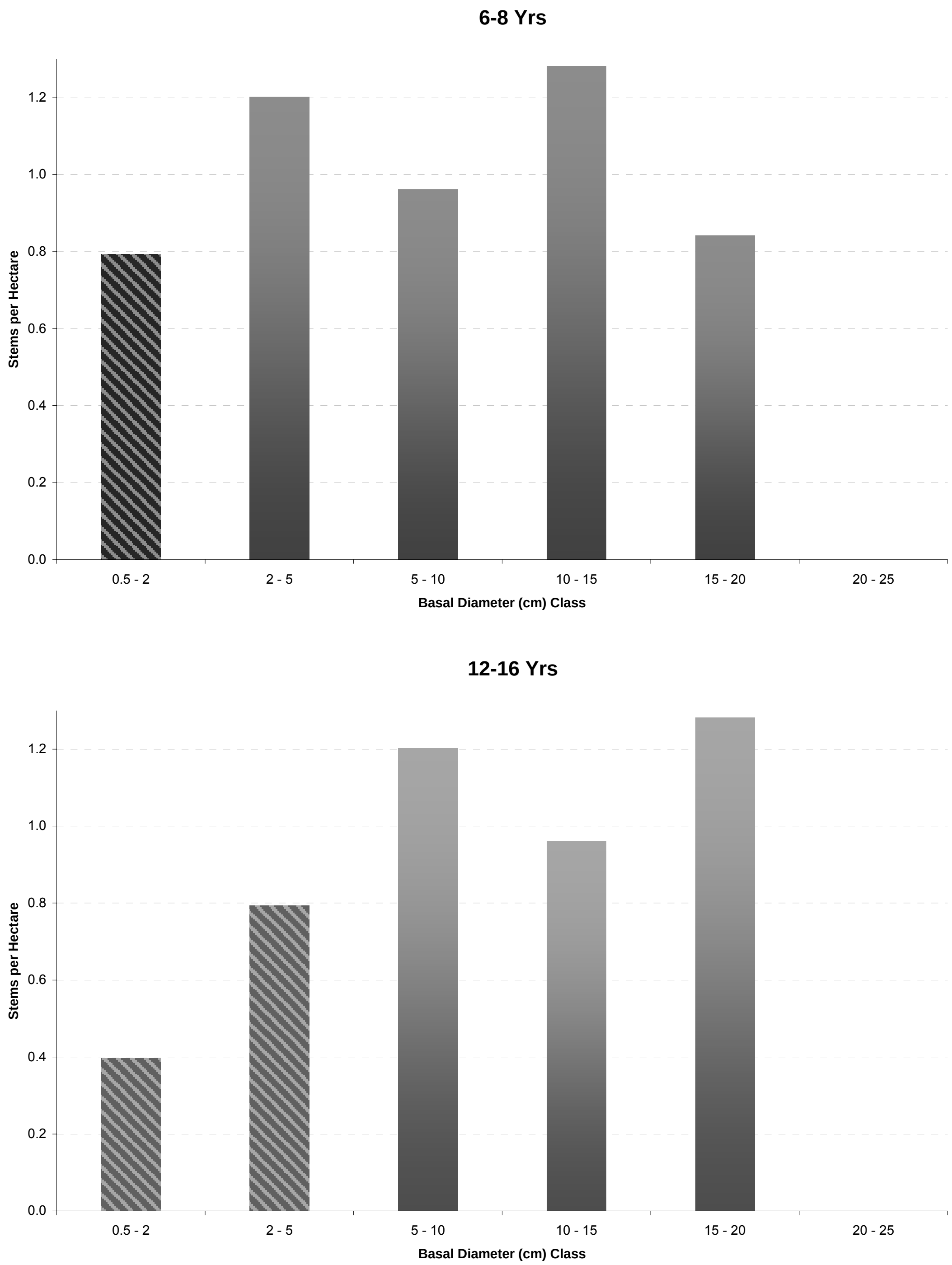

Figure 19: Projected densities of wild sandalwood in 6-8 and 12-16 years from present, for the surveyed islands

Using the historical harvest data as a guide (Figure 3 and Table 12), the total average annual harvest is 91 tonnes. Based on the estimate of 208 tonnes in Table 11 and allowing another 79 tonnes for other island sources (based on historic records), this rate of harvest would indicate near-exhaustion of the wild resource in perhaps five years, certainly by ten years. Plantation sandalwood will not be ready for harvesting for 10-15 years, so there will likely be a shortfall in sandalwood supply as well as loss of most of the wild genetic resource.

6.2.2 Planted Sandalwood

In Aneityum and Erromango significant sandalwood planting activity was observed in both the villages and as enrichment plantings around the survey areas. Two plantings were identified within the survey area in Erromango at 523m and 550m along the second transect, with approximately 50 and 30 saplings counted in each respectively. Both plantings were fenced to exclude cattle and the first planting (523m) consisted of 5-6 year old saplings with an average height of 4m, basal diameter of 4cm and DBH (1.3m) of 3cm. The second planting consisted of 3-5 year old saplings with an average height of 2.5m, basal diameter of 3.5cm and DBH (1.3m) of 2.5cm. One planting within the Aneityum survey area was identified at 835m along the first transect (Figure 20). This planting was not fenced, established in January 2007 and consisted of approximately 60 seedlings of about 10cm in height.

Sandalwood planting in Moso was confined to single tree plantings in village garden areas. Reports were recorded of difficulties encountered in successfully establishing sandalwood seedlings in areas beyond the village. No plantings were recorded within or observed around the survey area in Moso. Planting activities in Dixon's Reef Village and the Malekula survey area were non-existent, however two small nurseries with approximately 15 seedlings were observed in the villages.

Landowners reported difficulty in collecting seed from the trees located in the wild, which may be the manifestation of (a) the logistical difficulty in accessing the site, (b) predation by birds and/or (c) the potentially poor seed productivity of the population. A trip was made during the survey to Tisvel where significant planting activity was reported by landowners and some plantings observed within the village area. These landowners also reported that there were no significant natural stands that could be harvested commercially.

Figure 20: Sandalwood enrichment/garden planting recorded along Transect 1 in Aneityum. This planting was established in January 2007 where 60 seedlings were planted

6.2.3 Associated Vegetation

Non-metric multidimensional scaling of the quadrats according to their combination of possible associated species gave convergence after 44 iterations with a Stress 1 value of 0.153 in two-dimensions (Figure 21) which is a ‘fair’ representation of the original distances in the data set. In the two-dimensional representation of quadrat vegetation assemblages no distinct differentiation was detected between those quadrats with, from those without sandalwood. This indicates that within the vegetation communities that were sampled, quadrats with sandalwood trees were not positively associated with particular species or groups of species. In *Santalum spicatum* the best stands are reported to occur at the intersection of two vegetation types giving the sandalwood access to a wide range of hosts (Kealley 1991). Therefore while there is evidence that *S. album* forms preferential haustorial connections with certain hosts (particularly nitrogen fixing species) (Tennakoon, Pate et al. 1997) there may also be an advantage for hosting a diverse range of species.

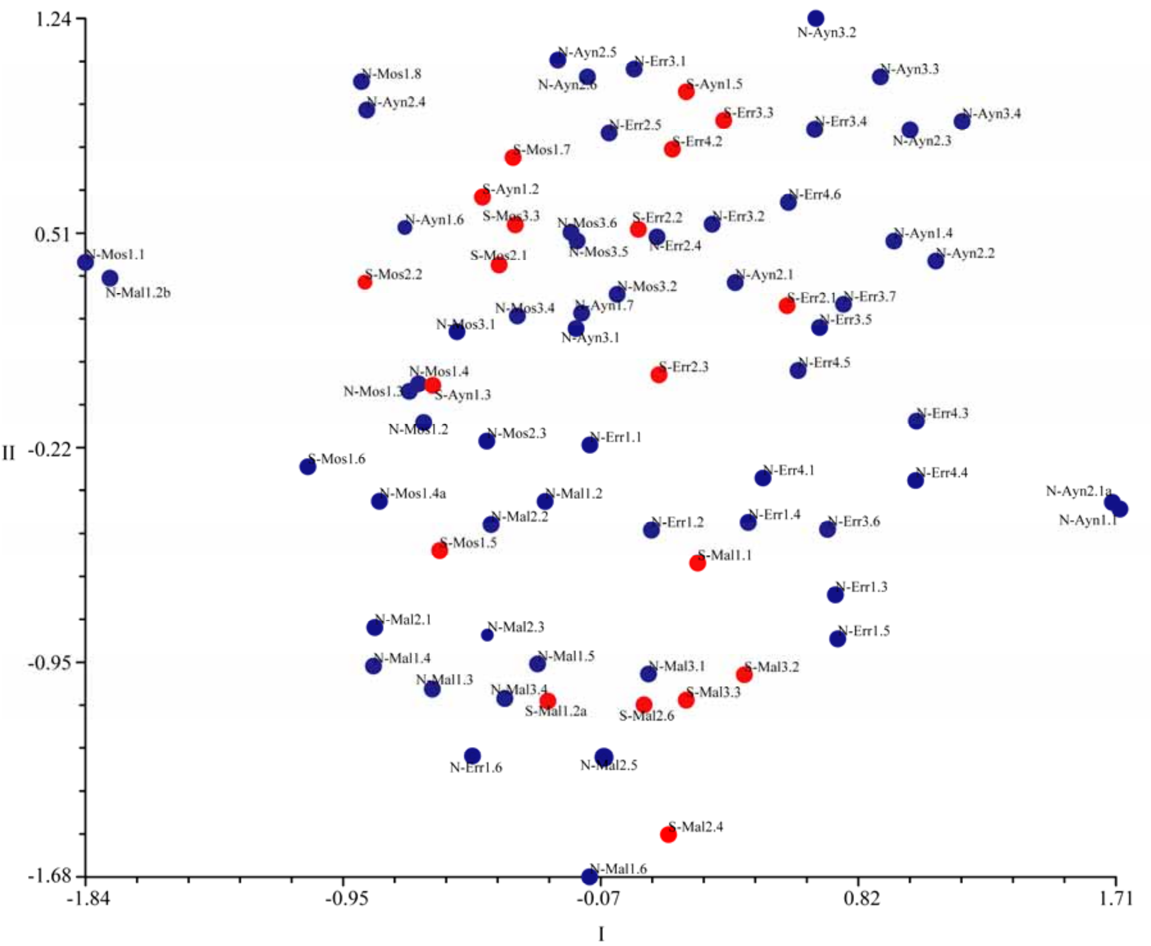

Figure 21: Non-metric multidimensional scaling (NMDS) showing positions of 74 quadrats in two dimensions, generated from a Jaccard similarity matrix using 109 associated species. Red points indicate quadrats with sandalwood present, while blue points indicate those quadrats without sandalwood

6.2.4 Cluster Density using Minimum Convex Polygons

Due to the strong clustered distribution of the sandalwood trees an effort was made to characterize tree density within these clusters. Densities were attained by creating minimum convex polygons (MCP) around trees that conformed to cluster distribution rules. Trees were classified as cluster members if they were aggregated into groups of 5 or more with each member within 30 meters of its nearest neighbour. These parameters were set based on the scale of the search radius when identifying neighbouring sandalwood trees. The area of these MCP's were then calculated and used to generate cluster tree density for three size classes. Size classes were determined by basal diameter. Table 12 lists the results of these densities, and Figures 22a through 22h display these cluster communities.

Table 12. Cluster densities by size class. Density values in stems per hectare. Size classes by basal diameter: #1 = 0.5 to 2.0cm, #2 = 2.1 - 5.0cm, #3 = 5.1 - 20.0cm

Cluster ID	Area (Hectares)	Total Trees	All Sizes Density	#1 Trees	#1 Density	#2 Trees	#2 Density	#3 Trees	#3 Density
Ayn1 C1	1.81	26	14.40	8	4.43	10	5.54	8	4.43
Ayn1 C2	11.38	22	1.93	2	0.18	9	0.79	11	0.97
Err2 C1	3.17	6	1.89	4	1.26	1	0.32	1	0.32
Err2 C2	22.52	12	0.53	9	0.40	2	0.09	1	0.04
Err2 C3	10.65	10	0.94	2	0.19	5	0.47	3	0.28
Err3 C1	5.43	13	2.39	2	0.37	4	0.74	7	1.29
Err4 C1	4.16	11	2.64	1	0.24	1	0.24	9	2.16
Mal2 C1	1.17	5	4.29	0	0.00	2	1.72	3	2.58
Mal3 C1	12.17	10	0.82	0	0.00	4	0.33	6	0.49
Mos1 C1	5.53	6	1.08	0	0.00	1	0.18	5	0.90
Mos2 C1	9.09	19	2.09	0	0.00	5	0.55	14	1.54

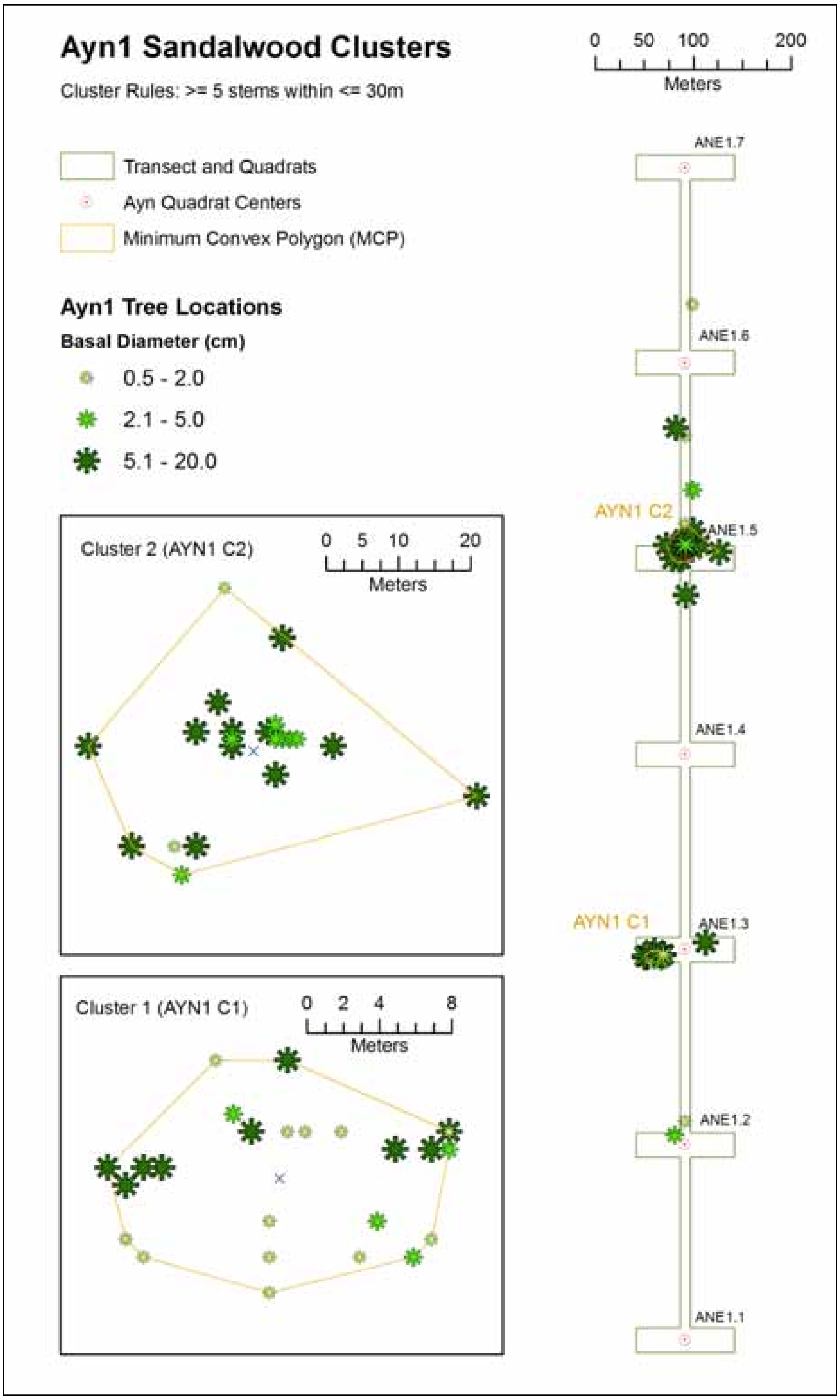

Figure 22a: Schematic transect and cluster diagram for Aneityum transect 1

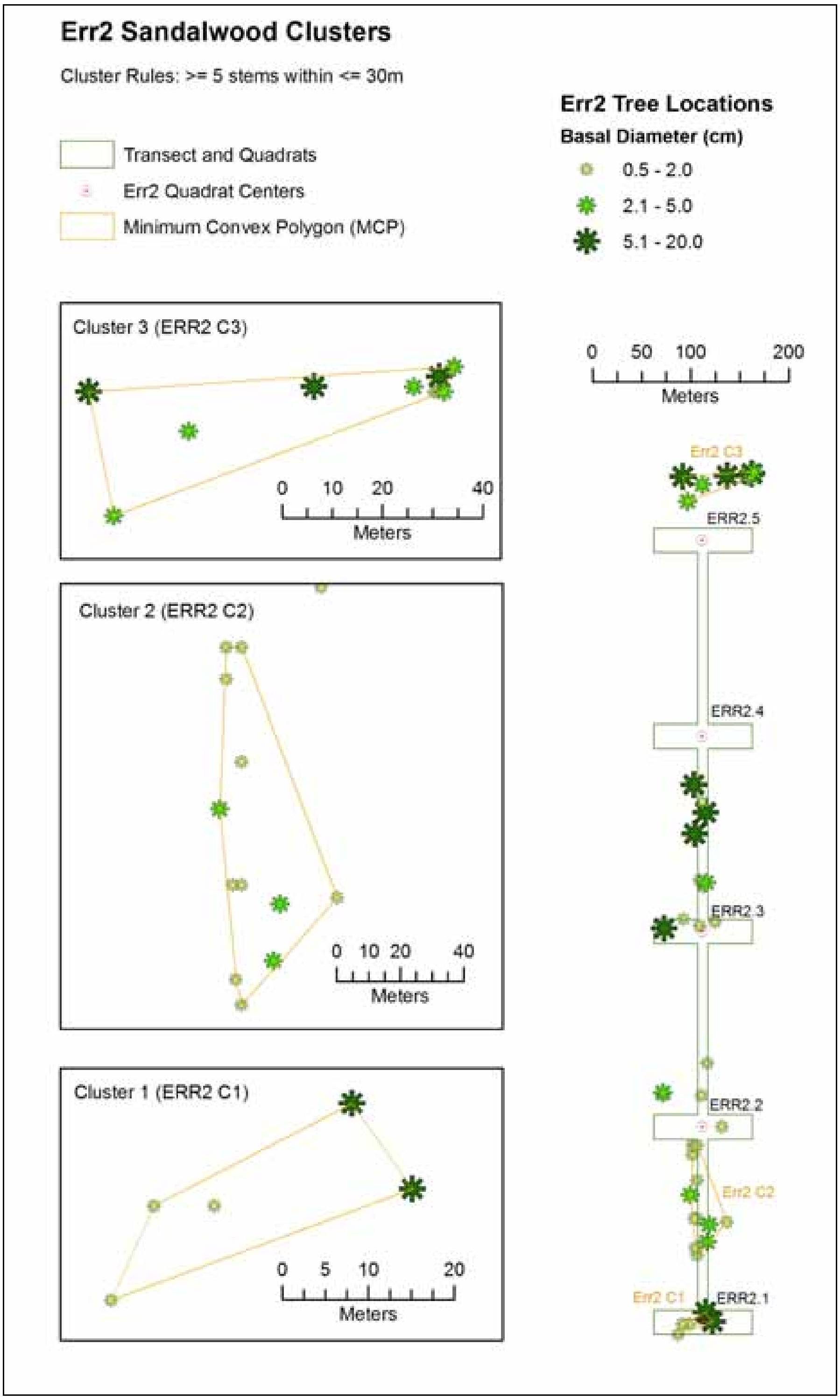

Figure 22b: Schematic transect and cluster diagram for Erromango transect 2

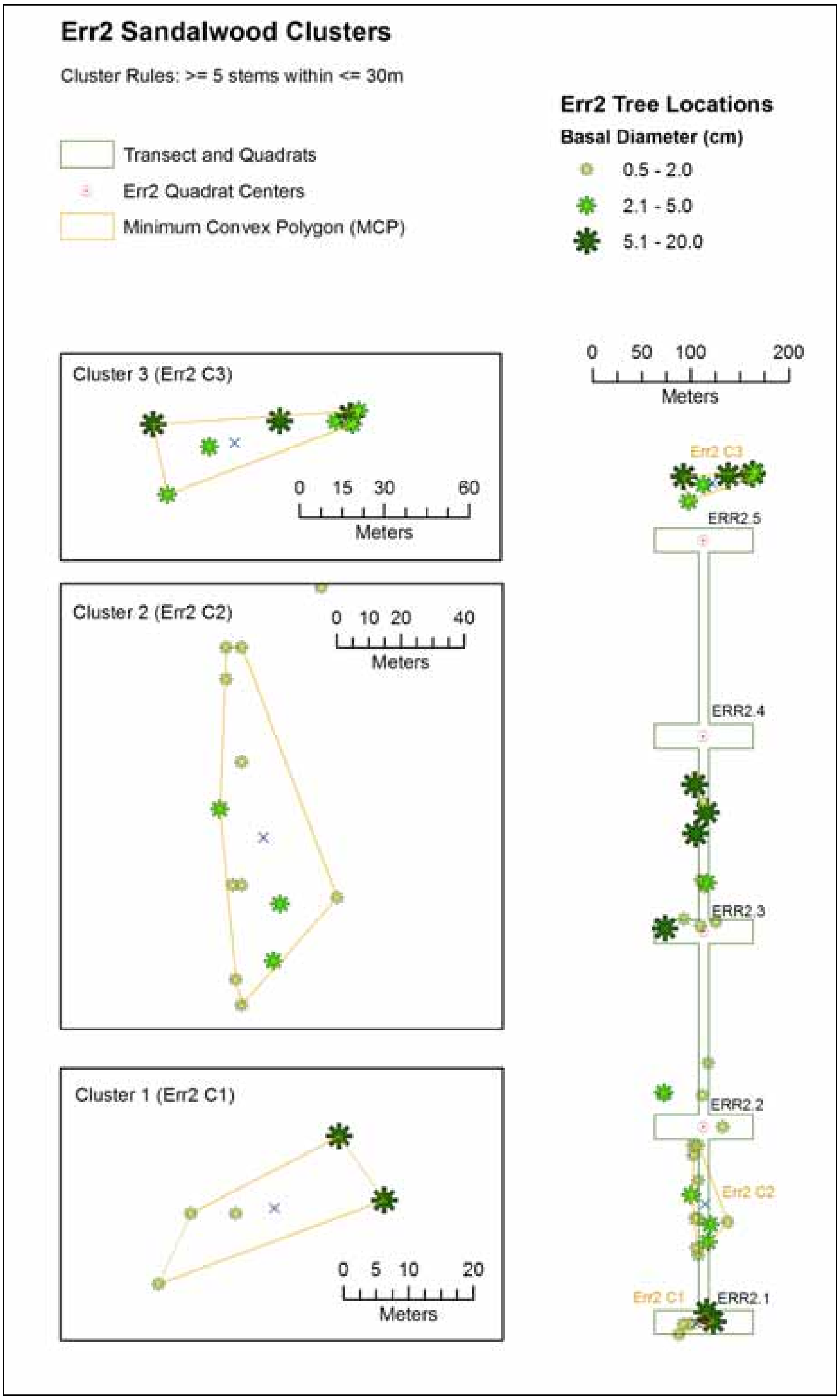

Figure 22c: Schematic transect and cluster diagram for Erromango transect 2

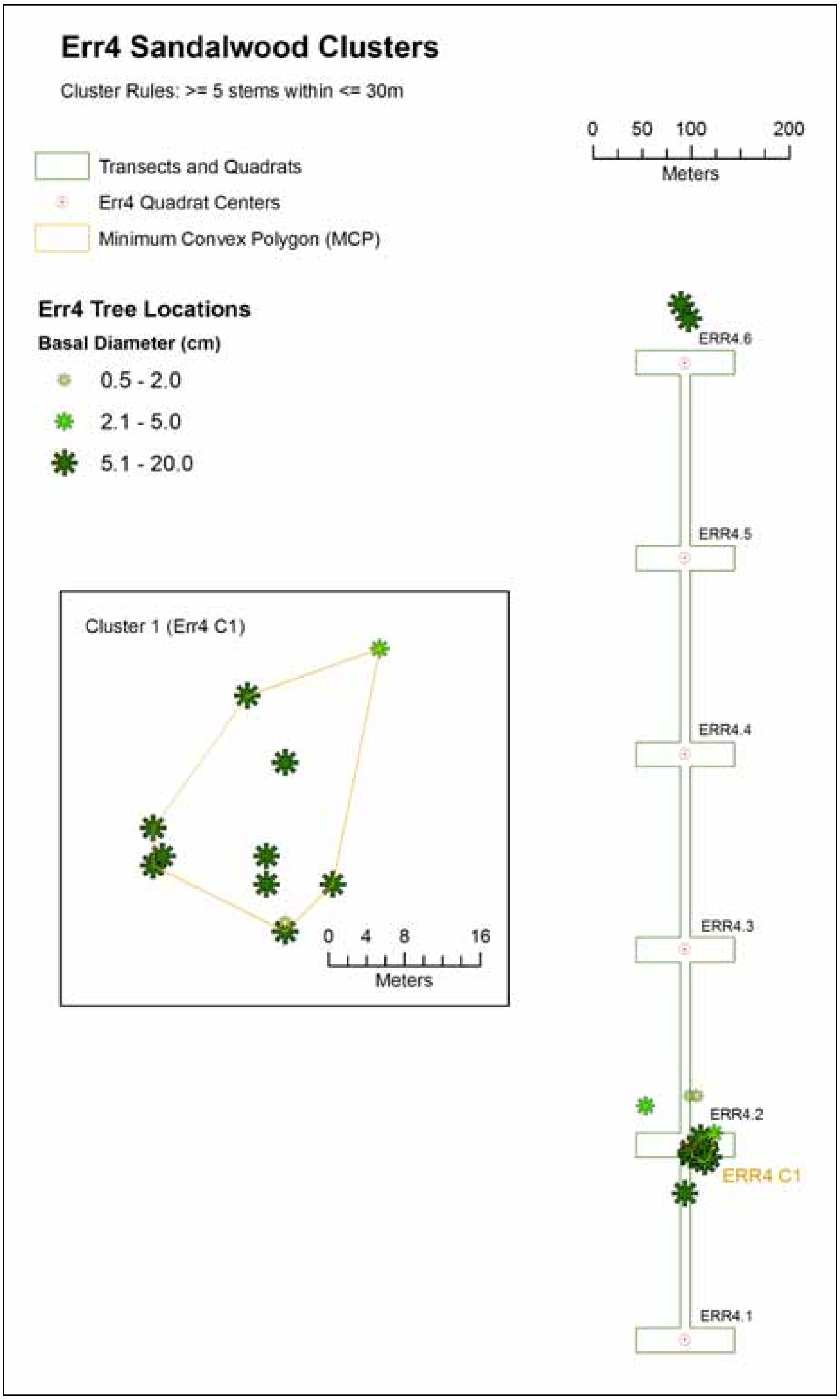

Figure 22d: Schematic transect and cluster diagram for Erromango transect 4

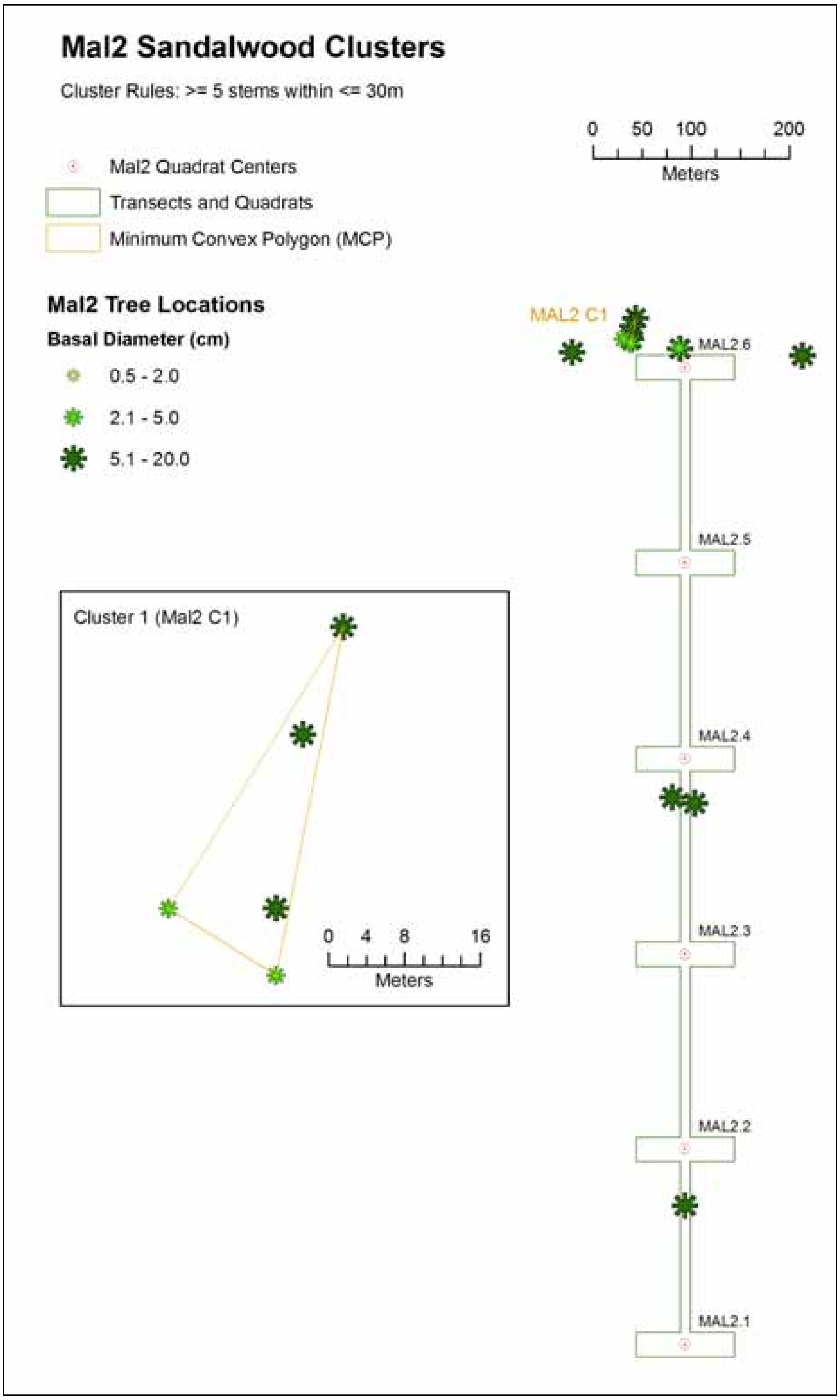

Figure 22e: Schematic transect and cluster diagram for Malekula transect 2

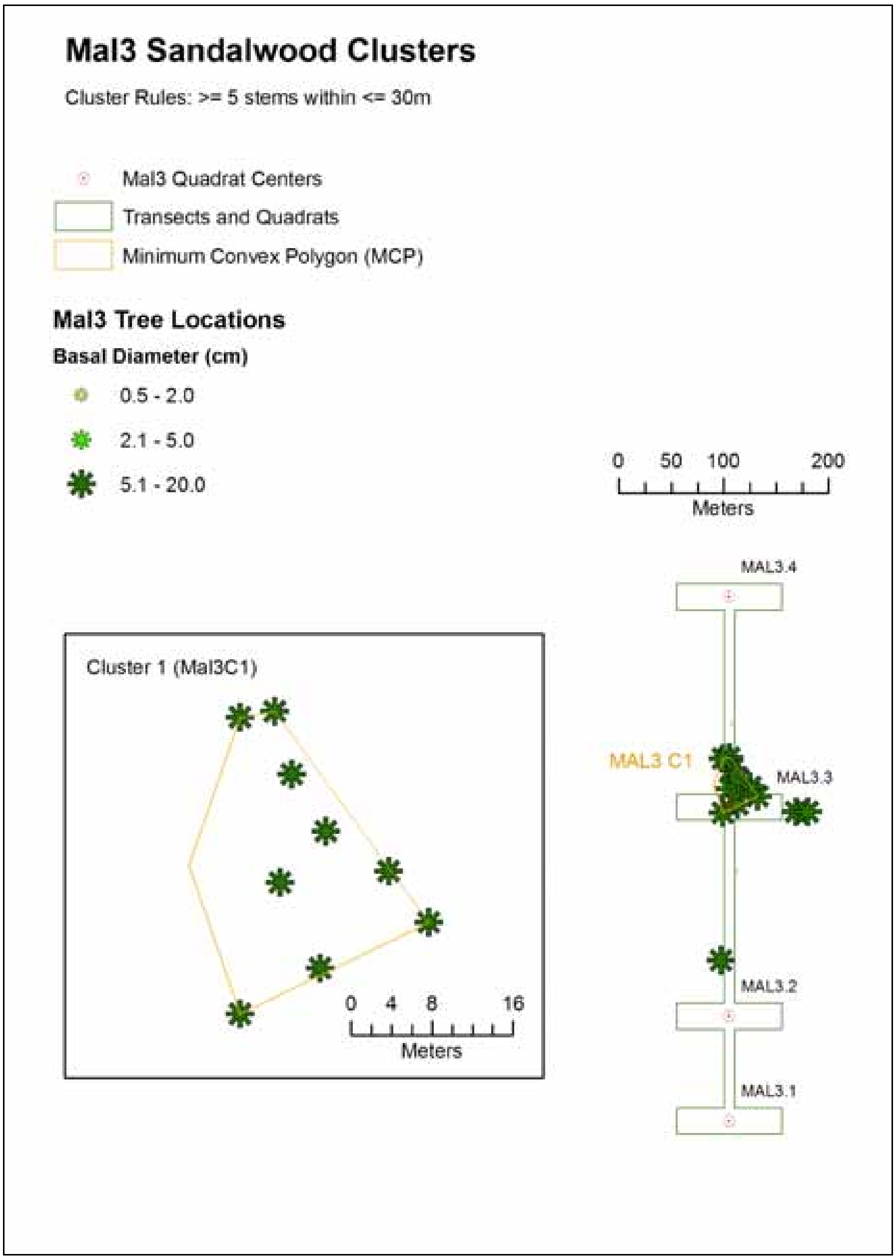

Figure 22f: Schematic transect and cluster diagram for Malekula transect 3

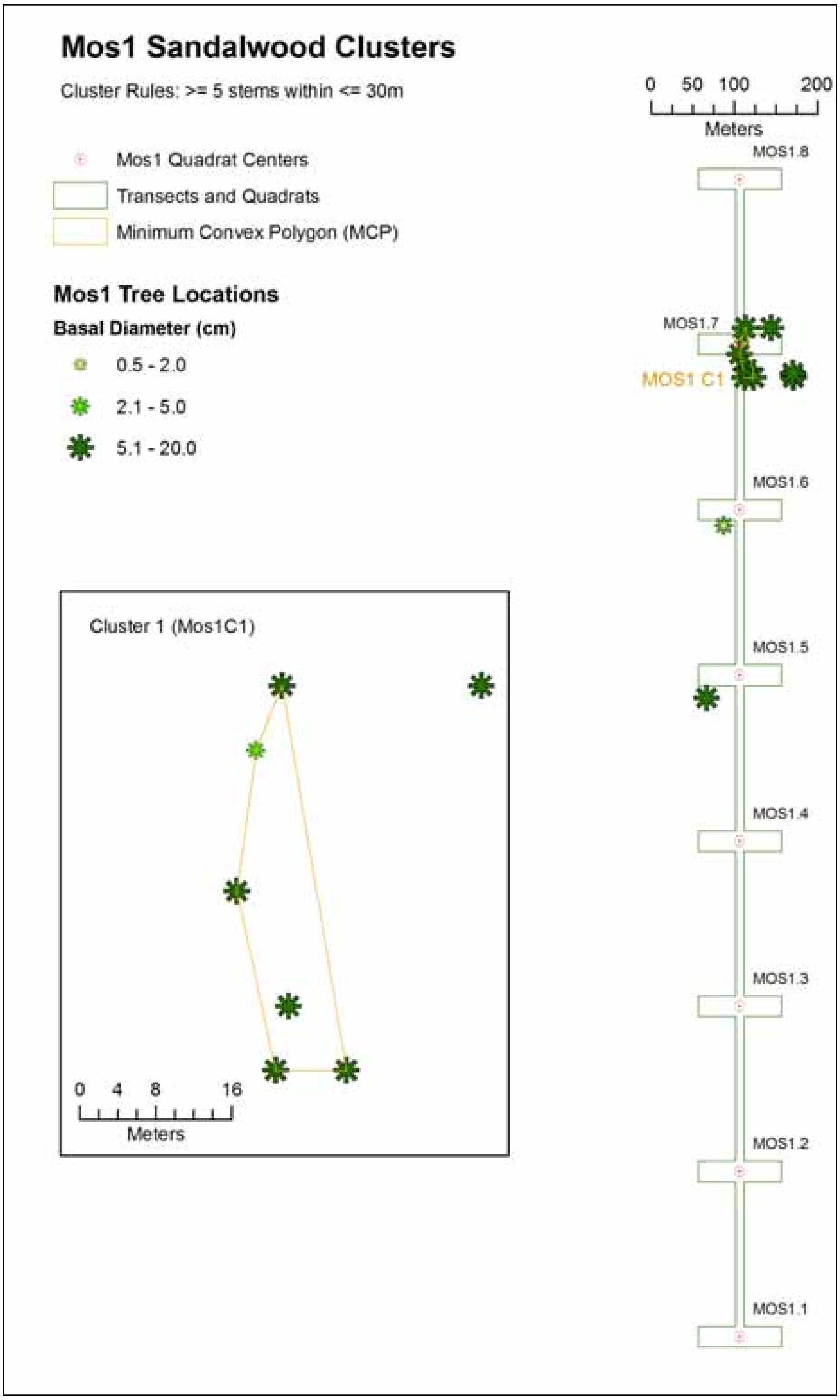

Figure 22g: Schematic transect and cluster diagram for Moso transect 1

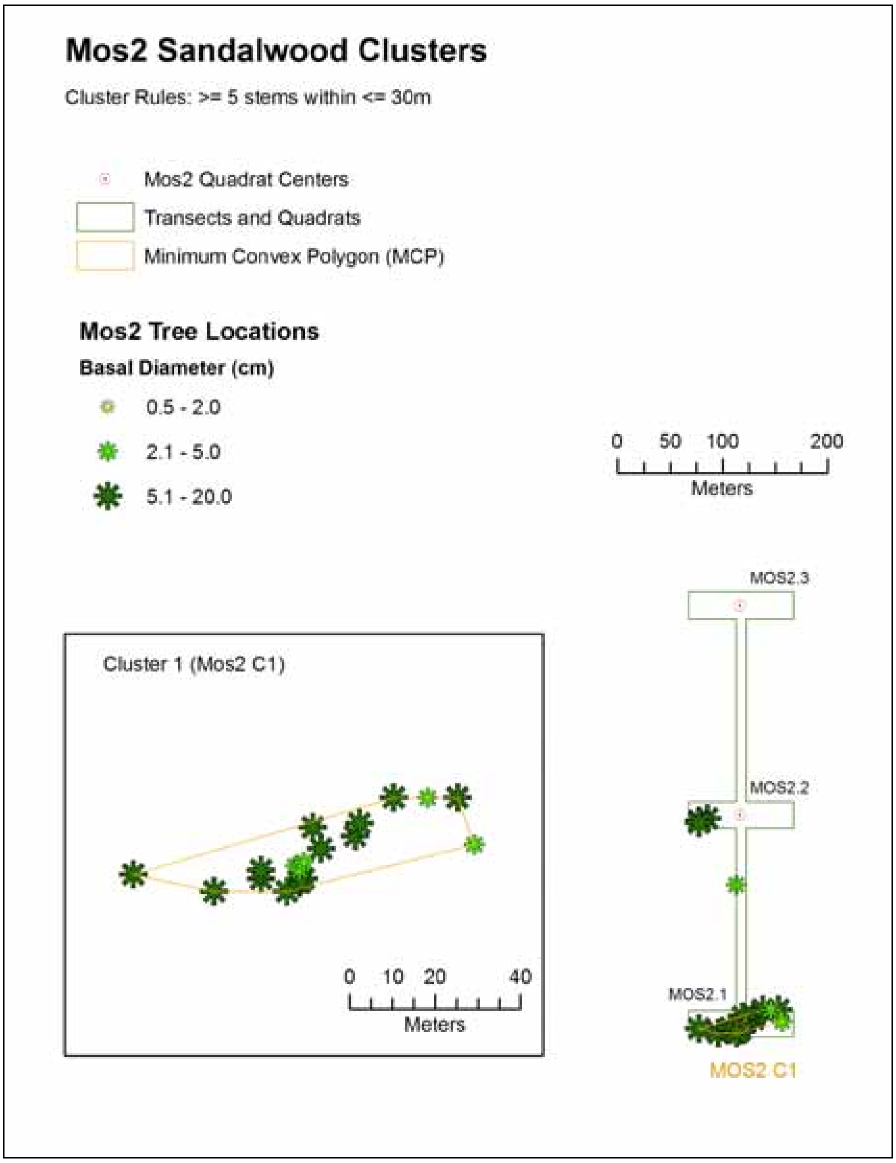

Figure 22h: Schematic transect and cluster diagram for Moso transect 2

7 Discussion

Quantifying the abundance and spatial distribution of *S. austrocaledonicum* in Vanuatu can present some challenges due to its broad, discontinuous but highly modified natural distribution. Very little systematic inventory work has been documented on any tropical Sandalwood species. In Western Australia the survey of temperate *S. spicatum* populations is often carried out along roadways where trees can be easily viewed in the open woodland vegetation. In Vanuatu *S. austrocaledonicum* often occurs in remote locations in dense 'midheight forest' with vine thicket and shrubby understorey. In such vegetation, line of sight is often restricted and the terrain can only be negotiated on foot. Given the logistical challenges of undertaking such an inventory, it is not surprising that a study such as this has not been undertaken previously. The paucity of reliable historical density data has been a major limitation of this study. Without reliable data is not possible to accurately quantify the magnitude of any changes in tree density over time. Our estimates of density reduction have been based on anecdotal reports, harvest data, and small data sets from some of our work during our 'Oil Quality Survey'.

An inventory of sandalwood resources in Erromango was undertaken during the National Forest Inventory (Baldwin *et al*. 1993). A total of 79 plots were surveyed and these authors estimated a total stocking rate of approximately 1 stem per hectare, which equated to approximately 90,000 individuals. Those trees with a DBH of >10cm constituted approximately 0.61 stems per hectare. Based on this stocking rate these authors recommended a continuation of the moratorium on large scale export of sandalwood from Vanuatu. In our survey the estimated stocking rate of 4.7 stems per hectare was much higher than reported by Baldwin *et al.* (1993), however those with a basal diameter of >15cm were present at densities of 0.49 trees per hectare. When this density information was extrapolated over the area of identified suitable habitat for sandalwood in Erromango approximately 62,000 trees exist with 6,500 trees of merchantable size.

7.1 Merchantable Sandalwood

The low density (0.4 individuals/ha) of commercially sized trees found in the surveyed populations is cause for concern, particularly given that the survey was carried out in locations where natural sandalwood is known to occur. It is recognised that accessible coastal locations were surveyed for Erromango, Aneityum and Moso where sandalwood is easily extracted by landowners. The field survey undertaken in Malekula occurred in very steep terrain that historically could only be accessed by a half day hike. In 2006-07 a significant logging track for *Intsia bijuga* had been blazed to the site allowing access by vehicle. The impact of this improved access on the harvesting of sandalwood is unclear. While the results of the study indicate commercial exhaustion of stocks in the areas surveyed it is possible that other more substantial stands remain. The location of such stands however, would protected by landowners who are cautious about publicising the information for risk of theft. This is particularly relevant given that the conservation sites sampled in 2004 for the 'oil-quality survey' in north Erromango (Page, Tate et al. 2005) were also among the sites to be extracted in the past few years.

This low density of merchantable sandalwood in the survey sites is likely to have resulted from exhaustive harvesting of these resources from the 1820s -1860s (Shineberg, 1967), followed by opportunistic harvesting and, over the past 30 years, modest but systematic harvesting. This intermittent but unremitting sandalwood extraction for 180 years is the root cause of the threatened status of the species in Vanuatu (Sam and Thomson 1999). The low density of commercially sized trees will have a short-term impact on the Vanuatu sandalwood industry. The low level of recruitment poses a more serious underlying problem for the persistence of natural sandalwood populations in Vanuatu.

7.2 Recruitment

The level of recruitment in both Moso and Malekula was negligible with no seedlings identified within the survey area. The recruitment levels in this study compare well with those measured in the 'oil-quality survey' where these populations had the lowest level of recruitment for all islands surveyed. In both of these populations there was also very little successful planting of sandalwood. Given the lack of recruitment and planting in these areas, they are the most threatened by commercial harvesting activities. Harvesting in these areas that have little to no recruitment would further threaten these populations and potentially lead to commercial extinction. It is recommended that an indefinite moratorium be imposed on the harvesting of sandalwood in these areas. The lifting of such a moratorium should only occur after sufficient evidence, collected through additional surveys, indicates an improvement in the level of recruitment or maturation of plantings.

The abrupt fall between the density of 'seedling/suckers' and saplings in Erromango may be the manifestation of two different impacts on the population. Firstly 68% of those in the seedling/sucker category were root sucker growth from previously harvested trees and therefore this level of recruitment is an artefact of human intervention. Secondly the high level of grazing by wild cattle (Figure 23) in this part of Erromango (Corrigan, Naupa et al. 2000) is likely to have a negative impact on the successful development of seedlings/suckers into mature trees. From the anecdotal historic reports it is recognised that Erromango probably had the greatest abundance of large sandalwood trees (Shineberg 1967). Recent harvest data indicate that Erromango is still the primary source of sandalwood in Vanuatu with an average of 51% of the annual harvest being sourced from the island for 6 years of data. It is likely that the harvesting activities of the 1800s represent the most significant reduction in the size and abundance of the natural populations. The harvesting activities of today are possibly having a much greater impact on the natural population in terms of its capacity to regenerate. The negative impact of this harvesting intensity in north Erromango is relatively greater than for other sites, as a higher proportion of the species genetic diversity is found there (Page, Tate et al. 2005).

While the recovery of the harvested trees in Erromango through suckering is a positive sign for the re-establishment of the sandalwood population, the high level of cattle grazing is a substantial threat to their survival. In Queensland *Santalum lanceolatum* is a highly palatable tree and regarded as excellent stock fodder (Everist 1986) and it is likely that *S. austrocaledonicum* has an equivalent or better palatability. The estimation of harvested trees in all areas is likely to be conservative, because it is probable that the survey team did not identify all of those that were removed and did not sucker, particularly those removed more that 24 months previously.

Figure 23. Heavy grazing of young sandalwood tree by wild cattle in northern Erromango.

If we extrapolate the data using data collected from previous studies it is possible to crudely estimate the volumes of heartwood being removed from these areas.

While it is acknowledged that this survey was only conducted on four different sites and may not be representative of all possible natural populations in Vanuatu, the data does highlight the overwhelming effect of current harvesting activities on these populations. During recent discussions with Forest Department and both current licensees there was a general consensus that the likelihood of finding any new large stands of sandalwood is low. The populations in northern Erromango, which have been recognized as being some of the most significant sources of sandalwood in Vanuatu, have been fully commercially exploited. If such harvesting intensity is carried out in other areas where substantial resources still remain, it is likely that they too will be commercially exhausted. The current low density of mature trees (0.2/ha) on Aneityum indicates that this population has not yet fully regenerated from the harvesting during the 1970s and early 1980s; with the low density of seedlings, suckers (0.2-2cm – 1.9/ha) and saplings (2-15cm: 2.1/ha) it is evident that these populations will still take considerable time to recover.

7.3 Future Sandalwood Industry in Vanuatu

While the growth of the sandalwood industry in Vanuatu is likely to decline over the short term, there is an optimistic outlook for medium- to long-term prospects for the industry. The basis for this optimism is the high level of sandalwood planting that is currently being undertaken at the village level. In all islands visited during this study, evidence of such activity was found, which in some areas was combined with collective organization to facilitate knowledge transfer and labour sharing. This increase in the level of planting by both smallholders and investment schemes throughout Vanuatu has led to a 1000% increase in the price of sandalwood seed from 500vt/kg in 2004 to 5,000vt/kg in 2007. Such a high demand for seed and seedlings has stimulated the development of a nursery industry that provides a short-term cash flow for sandalwood owners. This development may help to preserve sandalwood trees that bear good crops of seed as they are potentially a source of regular cash income. However these trees are likely to be only those that are easily accessible to allow the seeds to be collected before consumed by birds.

The Vanuatu Department of Forests has been actively working towards all of the objectives outlined in the Sandalwood Policy (2003) (Table 13). The success of their collaborative research to deliver scientific information related to sandalwood quality has resulted in the identification of elite selections that are now being used to develop superior planting material. Such research, combined with the extension work carried out by the Department has contributed to the stimulation of interest in planting by both smallholders and investors. The Department has also been successful in encouraging industry to adopt processing technologies to increase the quality of Vanuatu sandalwood products and increase the export value. This sandalwood inventory has led to a more empirical understanding of the remaining sandalwood resources in Vanuatu. However, the main challenge for the Department of Forest and the Vanuatu sandalwood industry is to improve the capacity to limit harvesting and administer, monitor and control the annual quota.

Table 13: The objectives of the Vanuatu Department of Forests Sandalwood Policy (2002)

- Increase sandalwood stock through replanting.
- Facilitate sandalwood industries to engage fully in processing locally
- Conduct and provide research information on sandalwood, to identify and promote the best sandalwood variety.
- Conduct inventory survey to establish information on sandalwood stock, to identify and promote appropriate management measures.
- Establish a proper control measure for better management of sandalwood harvesting and trading.

8 Conclusions and recommendations: Conservation of natural sandalwood populations In Vanuatu

Based on current evidence and data, the following strategies are proposed to ensure the conservation of natural sandalwood populations in Vanuatu:

Harvesting

- Reduce the annual harvest quota from natural populations to a sustainable level, given the lack of recruitment in many areas and a potential shortfall until plantation sandalwood becomes available.
- Retain separation of the sandalwood and 'sapwood' seasons to ensure transparency in quantifying annual heartwood harvest figures.
- Sapwood traded during the 'sapwood' season should only be sourced from trees harvested in previous sandalwood seasons. This should be monitored and enforced by the Department of Forests to ensure no immature trees are harvested and traded during this period.

Management

- Implement two purchase registers that clearly record purchases of heartwood and sapwood.
- Enforce the submission of Purchase Registers within 14 days of the month in which the sandalwood was purchased during the sandalwood harvesting season as outlined in the Sandalwood Order (1997).
- Implement a system to ensure that Purchase Register data are entered and analyzed within 5 working days of their receipt from licensees.
- Limit the length of the season once the annual quota has been met by effectively monitoring the Purchase Register data.
- Implement an improved system for entry, management and archiving of Purchase Register, Export Permit and Certificate of Origin data.
- Impose indefinite harvest moratoriums for the islands of Moso and Malekula that can only be lifted after reassessment of the natural.
- Seek funding to purchase appropriate scales that can be used to audit licensees during the natora and sapwood season.

Conservation

- Investigate the feasibility of establishing an effective network of sandalwood conservation agreements to conserve representative populations and genetic resources over the species range in Vanuatu. This might be in exchange for support for plantation establishment.
- Establish ex-situ plantings of randomly collected seed from all islands of Vanuatu with natural populations of sandalwood to serve as a living gene bank for the species.

Planting

- Undertake a planted resource survey to quantify the extent and maturity of both small holder and investment plantings. This information can be used to determine the most appropriate planting models for different economic objectives and help in the development of extension material. Information from the survey can also be used to determine the contribution and potential value of the Vanuatu sandalwood resource and the timing for implementation of required planted sandalwood quotas and legislation.
- Investigate potential options for registering significant plantations and ensuring resource owner rights to harvest planted sandalwood.

Research

- Establish sandalwood growth plots in conjunction with progressive sandalwood farmers to quantify the long term productivity of different planting models and across different climatic and edaphic zones.
- Further refine the mapping of suitable sandalwood habitat across Vanuatu that accommodates both climatic variables and environmental tolerances. Variables such as proximity to transport corridors and ports may also be of use to determine areas suitable for more significant investment in planting sandalwood.

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10 Appendices

10.1 Appendix 1: Natora (heartwood) volume inventory

Table 1: Natora (heartwood) volume inventory, based on field survey data from transects.

Island	Baseline	Basal diameter (cm)	Size Class	Basal Natora Regression	Basal Natora Weight (kg)	Stems/ha	Basal Natora/ha	DBH (cm)	DBH Natora Regression	DBH Natora Weight (kg)	Stems.ha	DBH Natora/ha
Aneityum	Ayn1	16.2	15 - 20	53.3	53.3	0.3	18.5	11.8	23.9	23.9	0.3	8.3
Aneityum	Ayn1	20.0	20 - 25	80.9	80.9	0.3	28.0	13.5	34.9	34.9	0.3	12.1
Erromango	Err2	15.0	15 - 20	45.0	45.0	0.5	22.2	11.7	23.3	23.3	0.5	11.5
Erromango	Err2	15.2	15 - 20	46.4	46.4	0.5	22.9	11.7	23.3	23.3	0.5	11.5
Erromango	Err3	16.7	15 - 20	56.8	56.8	0.5	28.0	12.6	29.0	29.0	0.5	14.3
Erromango	Err3	18.5	15 - 20	69.7	69.7	0.5	34.4	16.4	54.7	54.7	0.5	27.0
Malekula	Mal3	16.7	15 - 20	56.8	56.8	0.8	42.9	12.0	25.2	25.2	0.8	19.0
Malekula	Mal3	17.1	15 - 20	59.6	59.6	0.8	45.0	16.9	58.2	58.2	0.8	43.9
Malekula	Mal1	20.7	20 - 25	86.2	86.2	0.8	65.1	10.1	13.3	13.3	0.8	10.1
Malekula	Mal3	21.8	20 - 25	94.7	94.7	0.8	71.5	13.4	34.3	34.3	0.8	25.9
Moso	Mos2	16.4	15 - 20	54.7	54.7	0.3	18.9	11.4	21.4	21.4	0.3	7.4
Moso	Mos1	16.5	15 - 20	55.4	55.4	0.3	19.2	12.3	27.1	27.1	0.3	9.4