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PRODUCTION OF SANDALWOOD (*SANTALUM AUSTROCALEDONICUM*) FOR IMPROVED SMALLHOLDER INCOMES IN VANUATU

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ABSTRACT

Vanuatu is a Pacific Island nation with a wealth of forest resources that provide benefits to local communities on both subsistence and commercial levels. Sandalwood (*Santalum austrocaledonicum*) is sought for its fragrant heartwood oils and is harvested primarily from wild stands and sold to local exporters. It is the most lucrative of all forest products in Vanuatu and has been exploited commercially since the 1820's. Recent assessments of wild populations reveal that resources are now limited and, with current harvesting practices, are expected to decline further. However, considerable smallholder interest in establishing sandalwood plantings is being sustained by the current high international values for sandalwood products. Over the past 20 years the Vanuatu sandalwood price index has increased at an annual rate of 10% compared with 2.7% for the Vanuatu consumer price index (CPI). The rate of sandalwood planting in Vanuatu between 2000 and 2006 (14,250 trees p.a.) was significantly greater than for the previous 7 years 1993-1999 (478 trees p.a.). This study reveals that smallholder sustainable sandalwood production is economically feasible. A sandalwood agroforest harvested for heartwood has a Net Present Value (NPV) that is approximately 13.5 times swidden cropping, 1.5 times that of a pure stand of planted sandalwood harvested for heartwood and 280 times that of a sandalwood planting harvested for sapwood. The sandalwood agroforest returns the equivalent income to that of a Vanuatu Government employee with a technical college diploma, which is much greater than many smallholders can expect to earn from other activities. The low numbers of mature sandalwood accessible for seed collection and recent high demand for seed however, have led to considerable shortages of planting material to meet smallholder planting goals. This has resulted in significant price increases for sandalwood seed in all areas of Vanuatu. Recent research and development work has secured a genetic resource with improved heartwood oil quality. Thus the Vanuatu sandalwood industry will greatly benefit from deployment of selected genotypes to (a) increase supply of sandalwood seed available for agroforestry and (b) improve the heartwood oil quality of planted trees.

Key words: agroforestry, domestication, cost-benefit analysis, economics

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INTRODUCTION

The genus *Santalum* contains 16 small- to medium-sized tree species, which occur in parts of India, south-east Asia, Australia and the Pacific (Applegate *et al.* 1990, Barrett and Fox 1995; Harbaugh and Baldwin 2007). All species of *Santalum* are hemi-parasites, forming haustorial root connections with the roots of a wide range of species, including annual and perennial crops (Tennakoon *et al.* 1997; Tennakoon and Cameron 2006). Sandalwood trees (*Santalum* spp.) are highly valued for their fragrant heartwood oils and are recognised as one of the most precious non-timber forest products. Sandalwood oil has been used for centuries for religious and customary purposes and is now used internationally for cosmetics, aromatherapy, scenting of soaps, perfumery and medicines. The oil-bearing heartwood is also used for ornamental or ceremonial carvings or powdered for the manufacture of incense and other products valued in the international agarbatti market (Doran and Brophy 2005). The high demand for sandalwood products and the lack of commercial production of these trees has culminated in a sharp decline in the natural supplies of many sandalwood species (Bulai 2007, Butaud and Defranoux 2007, Rimbawanto and Haryjanto 2007, IUCN 2009).

Santalum austrocaledonicum Viell. is indigenous to the Pacific island nations of New Caledonia and Vanuatu. The species is commercially important in both countries and in Vanuatu sandalwood exploitation provides the primary means of income generation in many villages and supports both rural and urban employment. The harvest of sandalwood from natural stands was the first export industry in Vanuatu, commencing in the 1820s, and continues to be the major source of export revenue for many islands. Currently there are two sandalwood oil distilleries in Vanuatu which buy wild harvested wood from custom landowners and export both raw and processed product (Lui and Smith 2007). In Vanuatu the development of export industries can provide a basis for stimulating economic growth and sandalwood (*S. austrocaledonicum*) has featured prominently in the export earnings from native forests. This, however, has involved extractive harvesting from natural stands and has led to a serious reduction in the wild resources (Gillieson *et al.* 2008). The species is known to be amenable to agroforestry production (Corrigan *et al.* 2000), which if widely adopted by rural communities could alleviate harvesting pressures on wild stands while developing an economically significant smallholder agroforestry industry.

Sandalwood oil is a high value/low volume product that can be stored without deterioration, allowing economically viable transportation of its products from smallholder to processor and from processor to market (Bond 2006). The stable nature of the product enables commercially mature trees to be harvested at any time with minimal additional inputs. This allows smallholders to schedule harvesting when prices are higher and it also allows for selective harvesting when the farming family requires cash. With population pressures beginning to increase in many islands of Vanuatu there is a need for integrating commercially significant tree crops within fallow, boundary and/or community land. Sandalwood

plantings can be readily incorporated into existing swidden agriculture and also village and boundary plantings (Thomson 2006) to provide stability to family income and a buffer during periods of economic hardship.

The Vanuatu sandalwood industry has the potential to develop a niche market based on the organic and sustainable production of a highly-valued natural product, which benefits smallholder producers. Like many forestry investments, the planting of sandalwood is a long-term venture, e.g. commercial Indian sandalwood plantings in Australia are expected to mature approximately 15 years from planting (ITC 2009, TFS 2009). A seven-year sandalwood rotation for the production of sapwood, which can be used as an alternative filler in many agarbatti products, has been raised as an option for commercial smallholder production. The commercial viability of such an option is explored within this paper.

Anecdotal reports indicate an increase in smallholder and large-scale sandalwood planting over the past five years. Further expansion of sandalwood planting across Vanuatu could multiply current export earnings by many times and help satisfy an increasing international demand. The objective of this study was to determine current sandalwood planting activity by smallholders in Vanuatu and assess the financial costs and benefits of sandalwood cultivation under three different planting models relative to existing swidden agricultural practice.

MATERIALS AND METHODS

Woodlot Survey and Smallholder Interviews

Between 2003 and 2007, more than 1.9 million empty polybags were distributed by the Vanuatu Chamber of Commerce to smallholders. In 2007 a woodlot survey was undertaken where 1018 of these smallholders across 17 islands of Vanuatu were asked about the species, the date and number of trees they planted, and the density of planting.

More detailed interviews were undertaken with 25 sandalwood producers representing 6 different islands (Santo, Pentecost, Malekula, Efate, Erromango and Tanna) across Vanuatu in July 2008. A total of 206 questions were asked spanning the following seven broad topics: (i) land area and use, (ii) nursery management, (iii) site selection, plantation establishment and management, (iv) incidence of pests and disease, (v) marketing, (vi) level of investment, (vii) and input costs of garden and sandalwood farming systems. The responses to the socioeconomic questions were used to determine the average inputs and the financial returns from four planting scenarios, each of one hectare:

- Scenario 1: 4-year commercial smallholder garden with staple vegetables
- Scenario 2: 4-year commercial smallholder garden interplanted with sandalwood at a density of 3 × 4 m with 50% harvested at 15 years and the remaining at 20 years.

- Scenario 3: Commercial smallholder sandalwood planted at a density of 3 × 4m with 50% harvested at 15 years and the remaining at 20 years for heartwood.
- Scenario 4: Commercial smallholder sandalwood planted at a density of 2.5 × 2.5m with all trees harvested at 7 years for sapwood.

Economic Analysis

A cost-benefit analysis was undertaken to determine the relative economic benefits for smallholders of the four different planting scenarios for a single plot of land. Labour demands in each of the scenarios are highest in the first 4-years. In the 7- and 20-year scenarios there is little labour input from 4-years until harvest and therefore releases the smallholder to engage in other activities. In all scenarios the smallholder would have completed the most significant part of the investment in four years and would be working elsewhere. The economic comparisons between the planting models with shorter (scenarios 1 & 4) and longer (scenarios 2 and 3) rotations reflects the potential costs and benefits of a single investment on a given plot of land. Many smallholders already work gardens without sandalwood and the aim of the analysis was to determine (a) if including sandalwood during garden establishment (agroforest) would be of added economic value and (b) if the sandalwood agroforest was comparable to that of planting sandalwood exclusively (i.e. sapwood or heartwood). The high density (2500/ha) required for sapwood plantings naturally excludes any opportunity for smallholders to establish a garden simultaneously on the same site.

Heartwood yield estimates were based on the combined information from the 2008 interviews (data not presented) and data obtained from Hook (1997) and Taccconi and Mele (1995). The current price of heartwood was based upon the minimum price paid to landowners in 2009, which was 800 vatu (US$1 = 101.17 vatu) with a 20% premium for the use of seed derived from selected clones (Page *et al.* in press). During the four year growing period the labour input was assumed to be 33% greater in the garden with sandalwood than in the garden without sandalwood. Fencing costs were not allocated to the garden without sandalwood as typically household gardens are unfenced. Costs for transporting materials to the planting site were not included in either scenario, because they were highly variable depending on the site's location relative to the village and the local market.

All products were valued at current market prices regardless whether they were consumed or sold. The garden was considered to operate for a period of four years before soil nutrients were exhausted, although in reality this period would vary considerably between sites, depending on soil fertility at commencement of the project. In the smallholder garden interplanted with sandalwood, trees are planted at the same time as the food crops, and when the garden is abandoned to fallow, the natural vegetation re-establishes around the sandalwood, forming an agroforest. It is anticipated that sandalwood growth rates in these agroforests will be highly variable. Consequently it is assumed that only half of the trees

will be harvestable (roots, butts and trunks) in 15 years. The less productive trees will be allowed to remain on the site until year 20 when they will be removed. It is anticipated that the heartwood yield for both harvesting periods will be similar.

All input costs were expressed on a per-hectare basis in Vanuatu Vatu and converted into US$. Labour inputs for all scenarios were costed against the average daily wage of 1000 vatu. Comparisons between projects are based on Net Present Value (NPV) of returns per hectare and labour (per person per day) at a 10% discount rate, Internal Rate of Return (IRR) and Benefit-Cost Ratio (BCR) using the assumptions outlined in Table 1.

RESULTS AND DISCUSSION

Interest in sandalwood agroforestry in Vanuatu

The interest in planting sandalwood in Vanuatu crosses many socio-economic classes, and includes smallholder farmers, village chiefs and leaders, wage earners, professional workers, expatriate residents and foreign investors. The most significant sandalwood planting (130ha) in Vanuatu is that of a foreign investor in Efate. The combined efforts of sandalwood smallholders have also established

TABLE 1

Socioeconomic assumptions associated with the garden and sandalwood agroforestry models. 'Heartwood' refers to the long rotation (15 & 20yr) planting for heartwood and 'Sapwood refers to the short rotation (7yr) planting for sapwood. 1 US$ (American dollar) = 101.17 VUV (Vanuatu Vatu) on 02 August 2008

Gardening period (years)	4
Sandalwood 'heartwood' rotation (years)	50% 15 years, 50% 20 years
Sandalwood 'sapwood' rotation (years)	7
Heartwood yield (kg/tree) (15 & 20 years)	18
Sapwood yield (kg/tree) (7 years)	25
Heartwood yield (kg/ tree) (30 years)	57
Farmgate heartwood price (vatu)	1000 (US$9.88)
Farmgate sapwood price (vatu)	50 (US$0.49)
Sandalwood/ha 'heartwood) (3 × 4m)	833
Sandalwood/ha 'sapwood' (2 × 2m)	2500
Sandalwood seedlings (vatu/seedling)	200
Discount rate	10%
Sandalwood planting (seedlings/person/day)	35
Working day (hours)	7
Working week (days)	5
Working year (weeks)	45
Daily wage (vatu)	1000 (US$9.88)
Fertiliser application (g/plant) years 1–4	50
Number 'heartwood' trees harvested and processed per day	1
Number 'sapwood' trees harvested and processed per day	10

an equally significant resource of approximately 100,000 trees (equivalent to 120ha at a spacing of 3 × 4m). In the Vanuatu Agricultural Census (VNSO 2007) 2813 households surveyed indicated that they gathered naturally occurring sandalwood. The categories of use included firewood, building/repair, sale, for sawmilling, and seedlings for planting. This census allowed for each family to report more than one use. A total of 33 households indicated that they gathered sandalwood for firewood and 12 for building/repair. It is unclear whether households collected sandalwood for the sole purpose of firewood. It seems likely that the waste sapwood was burned following the removal of sapwood from the heartwood and sale of the heartwood, or alternatively it may have been used or sold as incense. During our interviews and discussions with sandalwood harvesters over a period of 5 years (independent of the National Agriculture Census), the only use for harvested sandalwood was for sale to local exporters, so the true extent of use for buildings/repair, although unclear, is probably minimal. Despite this lack of clarity the results are nested within the harvesting for sale and for planting and therefore these latter two categories account for all respondents. The total of these categories is 156 households greater than the total number gathering sandalwood (2813), which represents the number of households that gather sandalwood for both sale and planting (Table 2).

According to the agricultural census data, 60% of households working with sandalwood were involved exclusively with its planting. These households may represent those that have fully exploited their wild custodial resources and are now in the process of re-planting, or households without any custodial resources. Regardless of the demographic makeup of this category, it is encouraging that households planting sandalwood represent a much greater proportion than those harvesting for sale.

A major impediment to developing a genuine agroforestry-based sandalwood industry in Vanuatu is the scarcity of seed supplies (Lui and Smith 2007). The limited local supply of sandalwood seeds has resulted in a 2.5–20 fold increase in the unit cost of seed over the past 3 years (Table 3). A similar rise in the price of sandalwood seedlings has stimulated the establishment of a lucrative nursery trade in urban areas, but has put the goal of establishing sandalwood smallholdings beyond the reach of many subsistence farmers. Sandalwood

TABLE 2

The number of households that gather sandalwood for sale, planting or both of these purposes as extrapolated from the Vanuatu Agricultural Census (VNSO 2007).

Gather sandalwood for …	No. Households	% Households
Sale Only	959	34%
Sale & Plant	156	6%
Plant Only	1698	60%
Total	**2813**	**100%**

TABLE 3

The mean seed germination percentage and price US$/kg for commercially supplied sandalwood seeds for eight islands in Vanuatu. The commercial seed in Efate is sourced primarily from the islands of the southern Tafea province (Tanna, Aniwa, Futuna, Erromango and Aneityum). The number of seed per kilogram ranges from 3,300 to 4,500 depending on seed size.

Region	Island	Mean Seed Germination Percentage	2005 Mean Price (US$/kg)	2008 Mean Price (US$/kg)
South	Tanna	+80%	$2.50 – $12.50	$6.25 – $37.50
South	Erromango	70–80%	$6.25 – $12.50	$12.50 – $37.50
North	Santo	70–80%	$6.25 – $12.50	$87.5 – $250
North	Malekula	60–70%	NA	$62.50 – $187.50
South	Aneityum	40–50%	NA	NA
South	Aniwa	50%	$2.50 – $6.25	$12.50 – $37.50
South	Futuna	20–30%	NA	NA
Central	Efate		$6.25 – $12.50 (South)	$62.50 (South)

seed supply in Vanuatu comes primarily from the southern islands province of Tafea (Tanna, Aniwa, Futuna, Erromango and Aneityum). Although 81% of the smallholder interviewees in this study indicated that they had sufficient seeds for their sandalwood planting goals, seed availability in the northern islands is highly restricted: all smallholder interviewees from the three northern islands (Santo, Pentecost and Malekula) indicated they had insufficient sandalwood seed for their planting goals. The higher price for sandalwood seed originating in the northern compared with the southern islands (Table 3) reflects the higher quality heartwood oils and the more pronounced shortage of seeds from trees of the northern islands.

Sandalwood occurs naturally on eight main islands of Vanuatu (Santo, Malekula, Efate, Erromango, Aniwa, Tanna, Futuna and Aneityum), but another eight islands have areas with climatic and edaphic conditions suitable for the production of sandalwood (Malo, Aore, Ambae, Pentecost, Ambrym, Epi, Paama and Shepherd) (Gillieson *et al.* 2008). The latter eight islands, all north of the central island of Efate, have little to no planted sandalwood established in smallholdings. For the Vanuatu sandalwood industry to develop a sustainable niche market, it will need to provide consistent volumes of product over time. Establishing sandalwood production over a wide geographical area will enable the Vanuatu industry to increase overall volumes and mitigate the effects of natural and biological disasters. While the volumes of sandalwood seed in the Vanuatu marketplace have not been quantified, it is estimated that seed available in the open marketplace from wild stands may reach approximately 125,000 (~35kg) per year. With approximately 100,000 plants established in smallholdings between 2000–2006, this number may be sufficient to meet current planting rates. It appears however that the seed collection and distribution networks may not be sufficient to ensure all existing local seed demands are met. The bulk of the seed originating in the south does not appear to be traded widely, since a

substantially lower number of seedlings were planted in Efate or the northern islands compared with the southern islands.

Through the systematic evaluation of the wild populations of sandalwood across Vanuatu, a number of trees producing high quality heartwood oils were identified (Page *et al.* in press). Assuming that oil quality has high broad- or narrow-sense heritability, use of germplasm derived from these trees could improve the niche market opportunities of this product. Subsequently, the selected resource has been secured as a grafted seed orchard in the Vanuatu Forest Department nursery on the island of Efate. To ensure the participation of all relevant smallholders in the Vanuatu sandalwood industry there is a need to deploy this improved material over all islands with a climate and soil suitable for the production of sandalwood. This will facilitate wider adoption of sandalwood agroforestry and build a more substantial and high quality resource that will benefit the marketing of Vanuatu sandalwood. These developments can result in improved smallholder and national income and ultimately improve livelihoods.

Smallholder sandalwood agroforestry in Vanuatu

A total of 305 smallholders have established around 100,000 trees across Vanuatu with an average of 327 trees per smallholder (Table 4). Approximately 86% of the smallholder plantings were in the south of Vanuatu (Tafea Province) where natural sandalwood stands remain. Sandalwood plantings in Vanuatu are generally established using seedlings raised in village nurseries. Sandalwood seedlings are typically planted in garden areas within a swidden agricultural system and persist in the regenerated forest after the garden is abandoned. Early growth of sandalwood trees in such systems is greater in newly established compared with older (3–4yrs) gardens. Sandalwood seedlings are also being established in native forests as enrichment plantings and within the village as ‘specimen’ plantings. Interviews with leading sandalwood smallholders in Vanuatu found the average number of trees planted by them was 886. Furthermore, recent foreign investment in smallholder sandalwood has resulted in the establishment of 16 joint venture plantings in Erromango and Tanna, totaling 63,000 trees. The mean number of trees planted (4000) under these arrangements is 12.5 and 4.5 times the number measured in our 2006 survey and 2008 interviews respectively. Given the positive comments from both the investor and smallholder in these joint ventures, they may provide a model for increasing the rate of sandalwood planting in Vanuatu. While many farmers have already sought to plant sandalwood to augment future income, in many islands it is not possible to source sandalwood seeds, and deployment of seed or other propagating materials throughout the country is required to address this fundamental problem.

The 2007 Vanuatu Agricultural Census recorded 1854 people who were planting sandalwood. Using the mean planting rate of 327 trees per smallholder in the 2007 woodlot survey (Table 4), this may imply the establishment of about 607,200 trees. As the majority (66%) of smallholders in the woodlot

TABLE 4

The number of smallholders planting sandalwood, the mean number of seedlings planted per smallholder and total number of seedlings planted across nine islands in Vanuatu as measured during a woodlot survey in 2007.

Island	N	Mean Seedlings	Total Seedlings
Santo	5	372.0	1,860
Ambae	21	100.5	2,110
Malekula	13	238.5	3,100
Nguna	1	222.0	222
Efate	4	1,680.5	6,722
Erromango	76	478.2	36,340
Aniwa	92	238.5	21,939
Tanna	39	288.7	11,260
Aneityum	54	302.5	16,335
Total/Mean	305	327.5	99,888

survey planted at a density of 3 × 3 meters, this represents approximately 546 hectares of sandalwood plantings. Between 2000-2006 the annual planting rate was 14,270 sandalwood trees which was significantly ($P<0.05$) greater than for the previous seven years 1993–1999 when the annual planting rate was 478 trees. Therefore 96% of the sandalwood plantings recorded in the 2006 survey occurred between 2000–2006 (Figure 1). The marked increase in sandalwood planting rates since 1999 may have been influenced by the combined effects of: (i) the active promotion of tree planting in general, and sandalwood planting in particular (Vanuatu 2002), research and extension activities of donor funded sandalwood projects (Gillieson *et al.* 2008, Page *et al.* 2008) (ii) the distribution of planter bags free-of-charge through the Vanuatu Chamber of Commerce (iii) a decreasing wild resource (Gillieson *et al.* 2008) and (iv) increasing prices paid to landowners for sandalwood at an annual rate above that of the Vanuatu Consumer Price Index (Table 5).

A significant proportion of the Vanuatu's export earnings come from agriculture and exploitation of its timber resources, and growth in the forestry sector will largely come from plantation establishment (AusAid 2006). Vanuatu has a good capacity to source foreign exchange from processed timber exports and taxes (Bond 2006). Local value adding is a feature of the Vanuatu sandalwood industry, with local production and export of powder and essential oils (sandalwood). However, as national timber volumes have decreased in Vanuatu over the past ten years so too have royalties available to the Vanuatu Government. The decline in national timber volumes has led to a substantial increase in community and commercial production of local tree species including sandalwood. This development has subsequently led to a greater awareness and demand for higher quality germplasm, which can help to reduce the length of the rotation and maximise market value.

A sandalwood domestication programme is currently being implemented in Vanuatu to improve the fragrance qualities of the heartwood oils. The most

TABLE 5

Relative changes in Consumer Price Index and minimum price paid to smallholders for sandalwood heartwood in Vanuatu between 1980 and 2009.

Year	Vanuatu Price Index, 2000=100 1980–2009 (Vt)	Mean rate of change (%) in CPI Vanuatu	Sandalwood Price (vt)	Sandalwood Price Index 2000=100vt	Mean rate of change (%) in Sandalwood Price Index
1990	74.21	0	120	30	0
1991	79.01	6.47	120	30	0
1992	82.21	4.05	120	30	0
1993	85.14	3.56	300	75	150.
1994	87.1	2.3	350	87.5	16.7
1995	89.05	2.24	350	87.5	0
1996	89.87	0.92	350	87.5	0
1997	92.4	2.82	350	87.5	0
1998	95.44	3.29	350	87.5	0
1999	97.52	2.18	400	100	14.3
2000	100	2.54	400	100	0
2001	103.65	3.65	400	100	0
2002	105.69	1.97	400	100	0
2003	108.88	3.02	400	100	0
2004	110.42	1.41	500	125	25
2005	111.72	1.18	600	150	20
2006	114.07	2.1	600	150	0
2007	118.52	3.9	700	175	16.7
2008	122.31	3.2	800	200	14.3
2009	125.41	2.53	800	200	0
Mean		2.7%			10.0%

Sources: http://www.economywatch.com/economic-statistics/country/ and Vanuatu Department of Forests Annual Trading Season Announcements

valued oils are those that contain high levels of the sesquiterpenes α- and β-santalol. A total of 57 trees with elevated levels of α- and β-santalol have been selected from a survey of 264 trees across 7 islands encompassing a range of distinct genotypes (Page *et al.* in press). Scions were collected from these trees and grafted to seedling rootstock in the Forest Department Nursery in Efate. These grafted selections are currently being used to propagate more clones for deploying these selected genotypes across the country. Controlled hybridization among the selected genotypes will also be undertaken in order to establish progeny trials for selection of superior parents in the development of clonal and hybrid cultivars.

The agroforestry approach for securing future sandalwood supplies with genetically diverse and improved planting stock can potentially increase the total value of the industry since it has a number of advantages over the current wild-harvest industry. First, the planting of trees across a wider geographical area than the natural stands will facilitate improved distribution of economic impacts for smallholders across the country. Second, the integration of tree

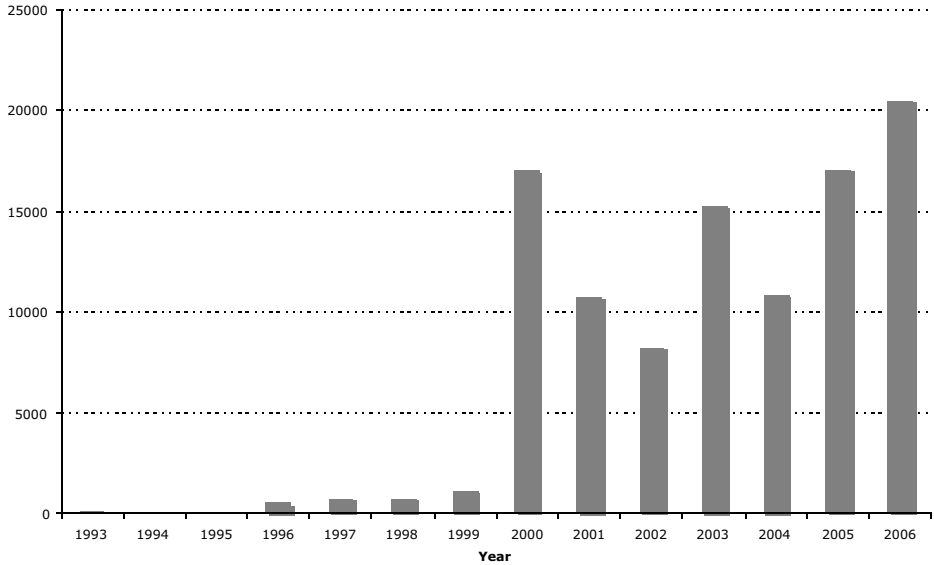

Figure 1. Numbers of sandalwood seedlings established in smallholder plantings in Vanuatu for all years between 1993 and 2006.

production within existing swidden agricultural systems can be undertaken with only minimal additional costs. Third, it can reduce the incidence of resource disputes, since ownership of planted trees is less likely to be challenged than ownership of wild trees. And finally integrated sandalwood agroforests can also help to reduce the dependence on, and subsequent overexploitation of natural sandalwood populations.

Value of sandalwood and proportion of income

Between 2005–07 the Vanuatu economy grew at approximately 6% p.a., which was a dramatic improvement compared with approximately 2% p.a. between 1990 and 2004 (AusAID 2008). This growth has been driven largely by an increase in international tourism with the number of arrivals between 2002 and 2007 growing at approximately 11%. However, little growth in agricultural productivity has been achieved in rural areas of Vanuatu (Fleming 2007, Reddy 2007), where approximately 78% of the people reside (VNSO 1999). The rural population is young (34% aged under 14) and growing at an annual rate of 2.3%. An increase in rural employment opportunities in Vanuatu is required to reduce urban migration and to limit the potential for civil tension. Improvement of agricultural productivity and household livelihoods may be achieved through adaptation of farming systems and incorporation of improved cultivars and the domestication of new crops (Tchoundjeu *et al.* 2010). Bond (2006) identified sandalwood oil as a high-value and low-volume product for development as a long-term cash crop for Pacific Island Countries. However, continued uptake

depends on sandalwood planting yielding higher financial returns than alternative activities.

A notable limitation to commercial sandalwood plantings is the long rotation relative to many agricultural crops. The minimum period before harvesting is estimated to be between 15 years (for good sites under good management) and 30 years (for less appropriate sites). This study has clearly demonstrated that the production of sandalwood on a shorter rotation for sapwood is not economically competitive with sandalwood agroforestry at both 15 and 30 years. Given the ambitious stocking rate of 2500/ha and the low current farmgate sapwood prices (US$0.49/kg) the short rotation production of sandalwood is marginal when considering it as an option to improve cash flow. The inputs for site preparation and annual management are the same for sapwood production as for the longer rotation sandalwood plantings (Scenario's 1 and 2). While sapwood production (Scenario 4) has reduced pruning inputs and pest control measures, the cost of planting and fertilizing 2500 stems (US$7167) is considerably higher than for the 833 stems ($2707) in scenarios 2 and 3.

Labour requirements

With an average of 5 individuals in a smallholder household (VNSO 2007) most of the labour associated with the production models would be carried out by members of the smallholder family. Although smallholders would generally not pay individual family members for their inputs, these costs were included in all production models. Sourcing labour outside the family unit was not an issue for any of those interviewed, but capital for paid labour was not available for 70% of smallholder respondents and a major constraint on the development of larger (>1ha) plantings.

Capital Inputs

The capital inputs will vary considerably between planting sites, but potential inputs across all sites were included in the models. Given the high palatability of sandalwood leaves, fencing would be essential in areas with feral or untethered cattle. However, fencing, may not be necessary in areas without the threat of cattle grazing. The threat of pests and diseases for sandalwood in Vanuatu is quite low. Sap sucking insects and leaf fungal disease can be an issue for humid sites at certain times of the year, particularly with younger saplings, but not a serious problem at present. While these pest issues are likely to affect growth, they are not likely to cause tree death. The use of chemicals to control such pests is therefore not necessary to ensure plantation survival and unlikely to be used. The most significant biological disease to sandalwood is *Phellinus noxius* (Brown Rot), which attacks the roots of the trees. The disease can rapidly spread within a sandalwood planting and has the potential to kill trees. The use of fungicides to control the disease is expensive and largely untested. Appropriate site selection and hygiene are the two most important factors to limit the ingress

of pests. While inputs such as fertiliser and pesticides are unlikely to be used by smallholders, these costs have been included in the sandalwood financial models to ensure that they, or other cost competitive organic options, can be accommodated within the budget if they are required.

Comparative System Profitability

Based on the assumptions of these scenarios the production of sandalwood heartwood and sapwood by smallholders in Vanuatu is economically feasible with positive NPVs for all scenarios at a discount rate of 10% (Table 6). The most profitable activity is the sandalwood agroforest (Scenario 2) which combines a 4-year food garden with a 15–20 year heartwood rotation. This sandalwood agroforest had the highest Benefit Cost Ratio (BCR) of all planting scenarios and a Net Present Value (NPV) that is approximately 13.5 times swidden cropping (Scenario 1), 1.5 times that of a pure stand of planted sandalwood harvested for heartwood (Scenario 3) and 280 times that of a sandalwood planting harvested for sapwood (Scenario 4).

The establishment of a smallholder garden (Scenario 1) the highest IRR (28%), above that of both scenarios involving smallholder heartwood production (Scenario 2 – 24% and Scenario 3 – 16%) (Table 6). This does not necessarily mean that the smallholder garden provides better returns than either of the heartwood plantings, since the heartwood plantings provide an NPV and BCR that is 9.1–13.5 and 2.0–2.1 times higher respectively than the garden. This ambiguous internal rate of return reflects the different period of investment between these scenarios where the discounting has a disproportionate effect between them. In the smallholder garden discounting only has an effect over 4 years compared with 20 years for sandalwood plantings for heartwood (Figure 2).

The economic feasibility of producing sandalwood sapwood is less clear where, although it has a positive NPV, it is only 5% of that for working a garden (Scenario 1) over 4 years and the return to labour (US$1.27/hour) is less than the minimum wage (US$1.43/hour) (Table 6). Given the significant investment in sapwood production and the low NPV relative to both garden and sandalwood heartwood production, it may be considered to be a low priority commercial activity. Intensive production (2500/ha) of sandalwood is also untested and the silviculture of such a density is likely to be problematic since it is hemi-parasititic and requires a host. Historically the trade in sandalwood in Vanuatu was restricted to the ‘desapped heartwood’ and sapwood trade was prohibited. In an attempt to fully utilize the harvested resource from natural stands the trade in sapwood was permitted, including chips from the cleaning of the heartwood, and branches. The sapwood trade led to confusion in the marketplace and harvesting of immature wild trees, which subsequently stimulated the introduction of restrictions for sapwood trade in Vanuatu. The trade in sapwood is also intermittent, where existing exporters in Vanuatu have needed to warehouse large stocks of sapwood until the market becomes available.

TABLE 6

Comparison of the income, costs and profits of the four scenarios. Figures are all in US$ based on the exchange rate of US$1=101.17vt on 2nd August 2008 at a discount rate of 10%.

Summary (NPV format) Type	Scenario 1 Garden (1ha)	Scenario 2 Garden & Sandalwood Heartwood (1Ha)	Scenario 3 Sandalwood Only (1Ha)	Scenario 4 Sandalwood Sapwood (1ha)
Rotation	4yr	4,15,20yr	15,20yr	1 × 7yr
Sandalwood gross receipts	$-	$28,754.61	$28,754.61	$15,850.74
Garden gross receipts	$12,219.51	$12,219.51	$-	$-
Total gross receipts	$12,219.51	$40,974.11	$28,754.61	$15,850.74
less average variable costs				
–Land preparation & planting	$249.66	$2,467.50	$2,467.50	$6,489.79
–Weed control	$1,871.45	$2,553.13	$2,553.13	$2,221.12
–Pruning	$-	$120.83	$120.83	$-
–Fertiliser	$-	$239.48	$239.48	$678.13
–Pest & disease control	$-	$383.03	$383.03	$226.81
–Irrigation	$-	$18.73	$18.73	$18.73
–Harvesting	$-	$1,620.49	$1,620.49	$1,473.88
Garden costs	$4,903.47	$4,903.47	$-	$-
–Total Average variable costs	$7,024.58	$12,306.67	$7,403.20	$11,108.47
equals Gross margin	$5,194.93	$28,667.44	$21,351.41	$4,742.27
–Capital purchases	$3,601.75	$6,881.80	$6,881.80	$4,665.29
–Total fixed costs	$3,601.75	$6,881.80	$6,881.80	$4,665.29
Total Costs	$10,626.33	$19,188.47	$14,285.00	$15,773.76
Farm profit	$1,593.18	$21,785.64	$14,469.61	$76.97
Internal rate of return	0.28	0.24	0.16	0.10
Benefit-cost ratio	1.15	2.14	2.01	1.00
Return to Labour	1.76	4.70	**5.74**	1.27
NPV relative to Scenario 0	1.00	13.67	9.08	0.05

The production of sandalwood obviously suffers, as do all forestry enterprises, from cash flow problems. In common with other examples of agroforestry, the combination of cropping activities with tree (sandalwood) production reduces the negative cash flow during the establishment years (Figure 3) to ensure the enterprise can be maintained until the first significant income when initial harvest is undertaken at 15 years. Sandalwood agroforestry also increases the efficiency of maintenance activities which benefit both crop and tree compared with crop production alone, which is particularly relevant to the high cost weeding activities.

The labour inputs associated with weeding in the first four years are comparable between all scenarios and relative to gross receipts weeding labour

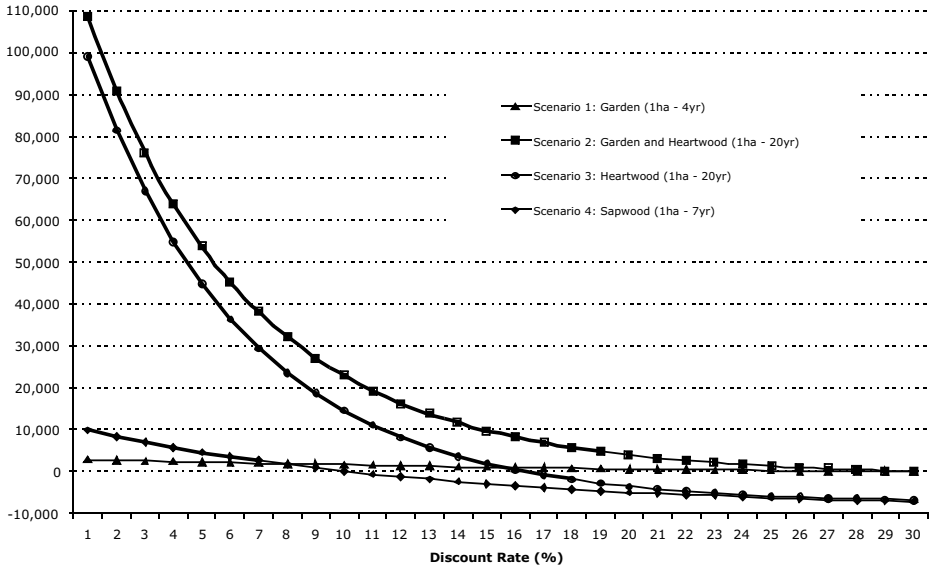

Figure 2. Net Present Value (NPV) profile for the four different planting scenarios across discount rates from 1–30%. The effect of discounting is most pronounced in the two 20-year Scenarios (2&3).

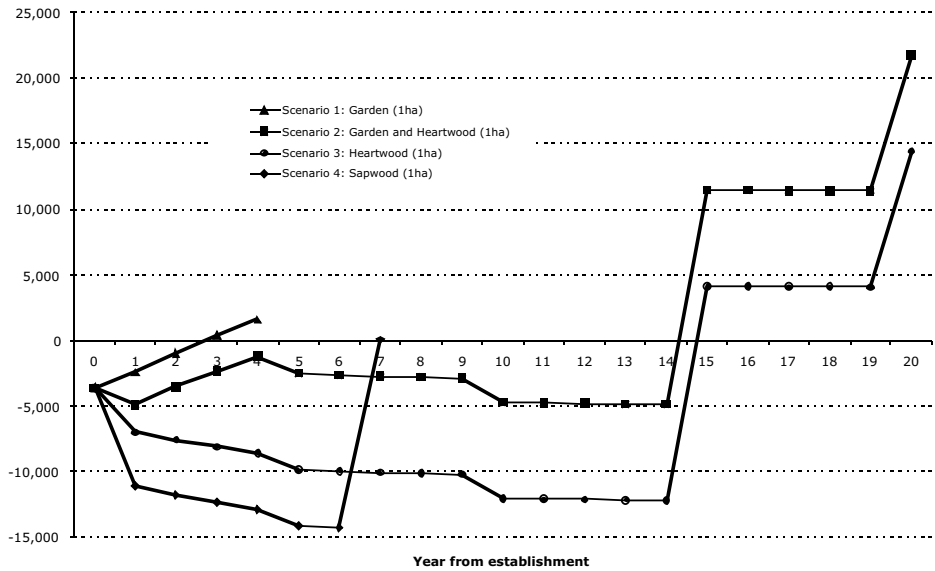

Figure 3. Accumulated cash flow US$ for the four different planting models

is greater in sandalwood plantings without gardens, where it represents 6, 9 and 14% in Scenarios 2 (heartwood and garden agroforest), 3 (heartwood only) and 4 (sapwood only) respectively. Return to labour represents the hourly wage rate that sets the NPV equal to zero at a discount rate of 10%. In the first three scenarios the return to labour is greater than the minimum wage of approximately US$1.40 (1000vt/day) (Table 6). This indicates that smallholders will be financially better off working a garden, a sandalwood agroforest or sandalwood planting than undertaking off-farm employment that attracts the minimum wage. The return to labour for the sandalwood agroforest (Scenario 2) is US$4.70/hr, which is equivalent to the average hourly rate for a Technician (CS2.2) employed by the Vanuatu Government. Such a position typically requires an education equivalent to that of a technical college Diploma. While the NPV of Scenario 3 is less than that of Scenario 2 it has a higher return to labour (US$5.74). The lower return to labour in Scenario 2 is the result from the higher labour requirements for the work associated with the garden.

CONCLUSION

Smallholders of Vanuatu have a unique opportunity to develop a commercially viable agroforestry industry by combining the production of sandalwood within their existing garden areas. The use of sandalwood under these agroforestry systems is appropriate since they incorporate a heavily exploited indigenous tree producing a high value, low volume and non-perishable product with export potential. The domestication activities currently being undertaken can ensure that in future the industry will utilize a high quality genetic resource that will be competitive in the international marketplace. With deployment of the improved genetic materials across all islands with a suitable climate, this will help make this lucrative industry more equitable. The commercial production of sandalwood within smallholder agroforestry provides an asset which may be used as collateral to secure microfinance and improve economic development. Sandalwood production is often referred to as the only long-term saving option for smallholders that can improve long-term financial security and ultimately their livelihoods. On a national scale the production of sandalwood may help to alleviate the harvesting pressures of contracting wild stands while providing a source of foreign exchange and government revenue.

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