



## Participatory value chain study for yasi sandalwood (*Santalum yasi*) in Fiji

L. A. J. Thomson, D. Bush & M. Lesubula

To cite this article: L. A. J. Thomson, D. Bush & M. Lesubula (2020) Participatory value chain study for yasi sandalwood (*Santalum yasi*) in Fiji, Australian Forestry, 83:4, 227-237, DOI: [10.1080/00049158.2020.1841442](https://doi.org/10.1080/00049158.2020.1841442)

To link to this article: <https://doi.org/10.1080/00049158.2020.1841442>



© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 04 Feb 2021.



Submit your article to this journal [↗](#)



Article views: 1403



View related articles [↗](#)




View Crossmark data [↗](#)



Citing articles: 5 View citing articles [↗](#)

## Participatory value chain study for yasi sandalwood (*Santalum yasi*) in Fiji

L. A. J. Thomson <sup>a</sup>, D. Bush <sup>b</sup> and M. Lesubula<sup>c</sup>

<sup>a</sup>Australian Centre for Pacific Islands Research, University of the Sunshine Coast, Sippy Downs, Australia; <sup>b</sup>Australian Tree Seed Centre, CSIRO, Canberra, Australia; <sup>c</sup>Ministry of Forestry, Colo-I-Suva, Suva, Fiji

### ABSTRACT

*Santalum yasi* (yasi) was first exploited in Fiji in the early 1800s and has been harvested periodically but heavily ever since. Yasi produces one of the most valuable sandalwoods, being high in  $\alpha$ - and  $\beta$ -santalols and typically meeting the East Indian sandalwood (*Santalum album*) ISO standard for sandalwood oil. Although wild yasi stands are now near to commercial extinction, they are being replaced by rapidly expanding smallholder plantings throughout the Fiji archipelago. A value chain study is presented for yasi in Fiji for a 35-year period (1984–2018). The study was undertaken in 2018–2019, in a participatory manner, through interviews and consultations with the key value actors, comprising yasi owners and growers, buyers, local buyers and processors, international buyers and processors, and the Fiji Government's Ministry of Forestry. The study's focus was on the main yasi-producing and -processing islands of Viti Levu, Vanua Levu, Kadavu and the Lau Group. The yasi value chain has been operating suboptimally, with modest returns to tree owners, growers and the Fiji Government, a failure to develop a local yasi-oil and value-adding industry, and, until recently, a lack of yasi replanting. An ongoing constraint to increased plantings of yasi in Fiji is a lack of practical and efficient regulatory and trading frameworks that can provide security of investment for growers, including legal verification (chain of custody) to meet market requirements and curb illegal harvesting. Key findings of this study are: (1) there is a lack of yasi brand recognition and development in the international marketplace due to its substitution for *S. album*, adversely affecting all actors along the value chain; and (2) there is an opportunity for branding based on yasi's natural properties and competitiveness. Recommendations are provided to improve the functioning of the yasi value chain in both the short and long terms for yasi tree owners (*i-Taukei* and smallholder growers), the Fiji Ministry of Forestry, and sandalwood buyers, processors and exporters. Given its high value and non-perishability, yasi has major and near-unique potential to contribute cash income to Fijian communities in remote island archipelagos. Fiji is well placed to develop a highly competitive and sustainable yasi sandalwood industry that delivers greater returns to tree owners, growers and processors through the development of high-quality plantings, enhanced governance and chain of custody, a yasi branding strategy, the development of local value-adding, and cooperation with major perfume houses and body-care-product companies.

### ARTICLE HISTORY

Received 3 August 2020  
Accepted 20 October 2020

### KEYWORDS

*Santalum yasi*; Fiji;  
sandalwood; value chain  
study

### Introduction

Sandalwood has near-unique potential to provide a source of revenue for remote island communities in Pacific Island archipelagos, associated with the high value of its heartwood and its non-perishable nature (Thomson 2006). Indeed, sandalwood (*Santalum* spp.) has long been important in the economy of several Pacific Island nations, including Fiji. In the early 1800s, major trade imbalances were developing between China and Great Britain (now United Kingdom) due largely to the latter's newly acquired taste for tea-drinking: sandalwood was one of the few commodities of high value that China was interested in trading with the West (Shineberg 1967). The first of the South Pacific sandalwood species to be exploited in the early 1800s was *Santalum yasi* Seem. ('yasi') in Fiji, with the species largely cut out by 1816 (Shineberg 1967). Since then, there have been periods of intense exploitation, usually at intervals of several decades due to the long recovery period of wild populations associated with both the species' slow growth rate and the near-total removal of large, heavy-seed-bearing trees. In more recent decades, Fiji sandalwood was heavily cut in 1985–1988 (918 tonnes of heartwood Bulai 1995) and 2006–2008 (511 tonnes of heartwood exported, Thomson 2013).

Most species of valuable sandalwoods (including East Indian sandalwood—*Santalum album* L., *Santalum austrocaledonicum* Vieill. and *S. yasi*) are 'commercially extinct' in their native habitats, with a global trend towards planted stands replacing wild-harvested sandalwood as the main source. Significant plantations have now been established in the Pacific, including in Vanuatu (Page et al. 2012), Fiji (Bolatolu et al. Forthcoming 2021) and Tonga (Motuliki Forthcoming 2021), as well as elsewhere, including northern Australia (Done 2007) and South Asia (e.g. Subasinghe et al. 2013). In Fiji, there has been a proliferation of sandalwood planting since the early 2000s. The interest and capacity of individual smallholders, home gardeners, communities and private companies in Fiji to grow sandalwood as a long-term investment derives from:

- a continuing sandalwood research and development (R&D) program by the Ministry of Forestry (MinFor), supported by its development partners and the private sector, including the German Agency for Technical Cooperation, the Commonwealth Scientific and Industrial Research Organisation/South Pacific Regional Initiative on Forest Genetic Resources, the

Secretariat of the Pacific Community, the Australian Centre for International Agricultural Research, and Pacific Reforestation (Fiji) Ltd (Jiko 1993; Bulai 1995, 2007; Dayal 2012; Bush, Thomas, et al. 2020);

- market forces i.e. the ever-increasing price paid for yasi heartwood in Fiji, up from USD 3 (FJD 3–4) kg<sup>-1</sup> in the mid-1980s (Bulai 1995) to approximately USD 46 (FJD 100) kg<sup>-1</sup> in 2019 (Thomson 2020); and
- MinFor's extension programs, especially its Sandalwood Development Program (Bolatolu et al. Forthcoming 2021).

Although sandalwood prices, including yasi, have been on an ever-increasing upward trajectory since wild sources neared exhaustion in the 2000s, there is a need to work with and better inform current and prospective sandalwood growers in Fiji. In particular, Fiji's sandalwood industry needs greater awareness of the global sandalwood market, sources of future production and competition to better inform their investment, plantation-development and management decisions.

This paper reports on a value chain study of the Fiji sandalwood industry with the objectives of providing a thorough documentation of value chain participation, providing greater transparency for all stakeholders, and identifying weakness and opportunities in the chain to more sustainably improve returns to all involved.

## Methods

There is an extraordinary diversity of methodologies and approaches to value chain analysis (VCA). In this study, we used a simplified VCA that has been developed and specifically adapted for use in the Pacific Islands by the Pacific Islands Farmer Organization Network (PIFON; Macgregor & Stice 2014). A participatory VCA study was conducted in 2019 and 2020 on the islands of Kadavu, Lau Group, Rotuma, Vanua Levu and Viti Levu. It involved interviews and *talanoa* (informal discussions and storytelling) with industry stakeholders, harvesters, nurseries, growers, buyers and processors, as well as correspondence and contact with sandalwood exporters and end-users/consumers. The period covered by the study was from 1984 to 2018.

This is an example of an innovation platform, a widely used participatory construct in agricultural research, connecting different stakeholders to achieve common goals. An innovation platform is defined as 'a space for learning and change'. It is a group of individuals (who often represent organisations) with differing backgrounds and interests, such as farmers, traders, food processors, researchers and government officials. The members come together to diagnose problems, identify opportunities and find ways to achieve their goals. They may design and implement activities as a platform, or coordinate activities by individual members.

The six steps in the PIFON VCA are: (1) drawing a value chain map; (2) populating the map with facts and figures; (3) identifying what each stakeholder/actor contributes to the final product and the returns they receive; (4) assessing the market (market analysis); (5) assessing strengths and weaknesses along the chain and identifying ways to take advantage of strengths and minimise weaknesses; and (6) developing a plan to improve the value chain.

## Results

The main findings of the Fijian yasi VCA are presented as tables, figures and appendices for each of the steps (steps 1–6). Participatory analysis was highly effective for defining the value chain structure, including the identification of major actors and of gaps and opportunities towards the top of the chain involving processing and marketing. Some data gaps remain, particularly in quantifying the inputs of certain actors, most notably growers. This makes the quantification of the benefits they receive less certain. The VCA in its present form does not extend to nursery and seed production, although these have significant value for some smallholders. Gathering more-detailed data on these aspects is a future priority.

### Steps 1 and 2: the Fiji yasi value chain map

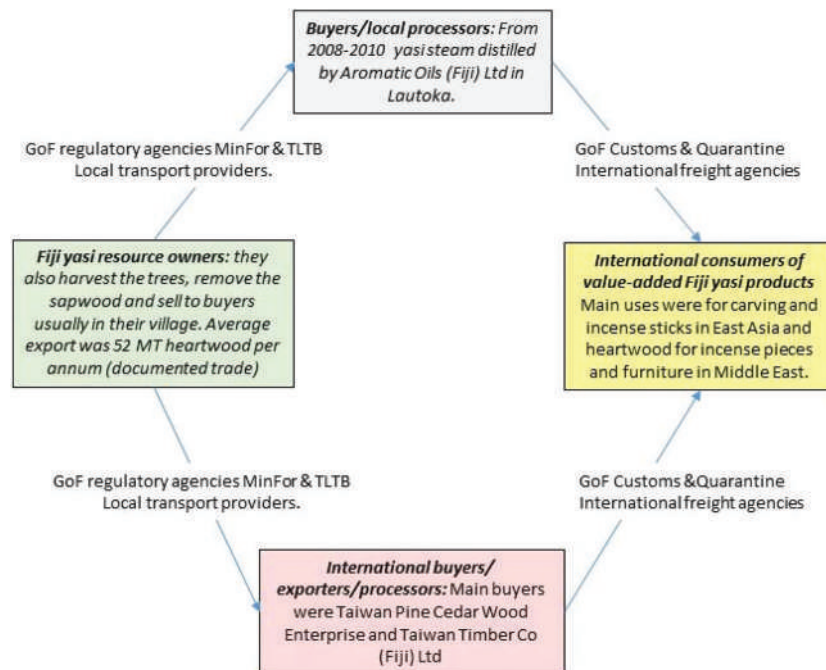
Four main groups of actors (those who buy and sell product as it moves along the chain) were identified in the Fiji yasi value chain: (1) sandalwood tree owners and harvesters; (2) buyers and local processors; (3) international buyers, exporters and processors; and (4) end-consumers. Two supporting actor groups (those who provide services to facilitate the movement of the product along the chain) could be distinguished: (1) Fiji Government agencies; and (2) local transport operators (Fig. 1). The sandalwood owners and harvesters were principally *i-Taukei* (Fijian) villagers on the islands of Kadavu, Vanua Levu and offshore islands (Bua and Macuata Provinces), Viti Levu (Nausori Highlands), Lakeba and Ono-I-Lau (in the Lau Group).

The main sandalwood buyers and local processors were Aromatic Oils (Fiji) Ltd. (Lautoka); Mr Jeff Allen (Suva, now in Vanuatu); Blue Ocean Marine Ltd (Suva); GoldHold Co. Ltd (Labasa); and Wee Kong Marine Product & Exporters Co. (Suva). International buyers, exporters and processors included Taiwan Timber Co. (Fiji) Ltd (TTC); Taiwan Pine Cedar Wood Enterprise (TPCWE); and Tropical Rainforest Aromatics (Vanuatu). The end-consumers of sandalwood products using Fiji-sourced yasi were in Asia (China; China, Hong Kong SAR; the Republic of Korea; Japan; Singapore; Taiwan Province of China; and Viet Nam), the Middle East (Dubai and Saudi Arabia) and Australia.

The supporting actors comprise Fiji Government ministries and agencies and local transport operators, both terrestrial and marine. The government agencies of the *i-Taukei* Land Trust Board (TLTB, formerly known as the Native Lands Trust Board or NLTB) and the Fiji Ministry of Forestry (MinFor, formerly the Forestry Department) are responsible for approvals to cut and sell sandalwood. MinFor also undertakes R&D and provides improved germplasm, extension services, risk management (pests and diseases) and (most importantly) a system to ensure legality—the foundation for international trade. During the 1980s and 1990s, however, the Forestry Department had limited involvement in regulating the trade, aside from impounding sandalwood that had been illegally procured. The NLTB collected the Sandalwood Regeneration Levy (10% of price paid); ostensibly this was to support replanting by the Forestry Department and landowners, which, however, did not take place apart from a small trial planting on Kadavu.

The *i-Taukei* yasi owners harvest the trees, remove the sapwood and sell to buyers or middlemen, usually in their own villages. The quantity of harvested heartwood fluctuated

## Fiji Yasi Value Chain – 1984–2018



**Figure 1.** Yasi value chain in Fiji between 1984 and 2018. The Fiji Government (GoF) plays a critical role in regulating interactions between international and Fijian private-sector actors

MinFor = Ministry of Forestry, Fiji; TLTB = i-Taukei Land Trust Board.

dramatically between 1984 and 2018, with maxima of 285 tonnes in 1986 and 306 tonnes in 2008 and an average yield of 52 tonnes annum<sup>-1</sup>. From 2008 to 2010, yasi heartwood was procured and steam-distilled by Aromatic Oils (Fiji) Ltd in Lautoka, with 1330 kg of yasi oil exported in 2011 at a price of USD 660 kg<sup>-1</sup> (FJD 1180). TPCWE and TTC (Fiji) Ltd were the main international buyers of yasi in the 1980s and 1990s. Buyers from these companies or their local agents/middlemen (and other companies) would visit Fijian villages and buy cleaned heartwood. Typical village-gate yasi heartwood prices increased from USD 2.50–7 kg<sup>-1</sup> (FJD 3–8) during the 1980s to USD 9 kg<sup>-1</sup> (FJD 13) in early 1991, USD 22–31 kg<sup>-1</sup> (FJD 45–56) in 2009–2011 and USD 48 kg<sup>-1</sup> (FJD 100) in 2018. The heartwood was exported mainly to East Asia and the Middle East for further processing or sale as oil (blended or substituted for *S. album* oil), incense sticks and carving-wood.

TPCWE was one of the main buyers of Pacific sandalwood in the 1980s and 1990s, especially from Tonga and Fiji. In 1984, this company paid USD 0.4 kg<sup>-1</sup> (TOP 0.50 kg<sup>-1</sup>) in Tonga and USD 0.9 kg<sup>-1</sup> (FJD 1 kg<sup>-1</sup>) in Fiji for cleaned *S. yasi* heartwood, despite the Tongan yasi – known locally in Tonga as ‘ahi – being of discernibly higher quality. The procured sandalwood went to Taiwanese industries for incense, which was the main use (but also its lowest value); carving, including for fans and pens; perfume; and high-quality furniture, with the best grades exported to Saudi Arabia. From 1985 to 1987, the Fiji Government tender price was FJD 3.65 kg<sup>-1</sup> (USD 3.40 kg<sup>-1</sup>), but it was a struggle to make a profit during this period, due partly to the Taiwanese import tax (USD 1.70 kg<sup>-1</sup>), which was abolished in 1987. After 1987, the price paid for yasi in Fiji was USD 7 kg<sup>-1</sup> (FJD 8–9 kg<sup>-1</sup>), but yasi trade was more profitable in this period due to changing market conditions and costs.

The price paid by end-consumers of Fiji yasi products varied depending on product and location and is not publicly documented; according to Taiwanese buyers in Fiji, however, it was at least 3–4 times the price that was paid to the tree owners/harvesters. Note that the price paid by end-consumers of sandalwood products in East and South Asia and the Middle East in the 2000s was approximately 3–6 times that of the retail selling price; for example, in a highly regulated market in South India in 2003, private sandalwood growers in Karnataka were paid an equivalent of USD 3 kg<sup>-1</sup> of *S. album* heartwood that had a retail price of USD 19 kg<sup>-1</sup>; in 2008, the respective prices were USD 19 kg<sup>-1</sup> and USD 60 kg<sup>-1</sup> (Dhanya et al. 2010).

### Step 3: identifying what each actor contributes to the final product and their returns

**Tree owners and harvesters.** Traditionally, the sandalwood harvest was of wild trees, and the owners were barely involved with the resource until harvest time and processing. Now, owners are increasingly involved in managing wild trees, including form pruning and the removal and reduction of the crowns of overhanging trees. Owners are also increasingly involved in enrichment planting of wild stands, including tending for 20–25 years. The costs of these practices have not been well studied but may entail two weeks’ work per tree for small plantings, with efficiencies for larger-scale plantings. Protection from theft is an additional cost, especially when the owners do not reside near their plantations. Owners also incur the cost of procuring sandalwood seedlings and host plants from MinFor nurseries and increasingly from private nurseries. Tree owners/growers likely receive around 20–25% of the price of heartwood paid by final customers, depending on products and



markets (Fig. 2). Their main risks arise from planting sandalwood too densely and overwhelming the available hosts; not providing appropriate long-term hosts, which can result in growth stagnation; the occurrence of higher-intensity category 3–5 cyclones as a result of climate change; and theft. Also, small growers lack market power and information and therefore tend to be price-takers.

The harvesters identify mature yasi trees containing heartwood and harvest trees (including the main roots) by manual cutting and excavation. The lighter-coloured sapwood is removed using large knives (usually cane knives or machetes). The de-sapped heartwood is then stored and dried, ready for sale. The costs of this manually intensive wild sandalwood harvesting and traditional processing have not been well studied or documented: the labour inputs vary greatly from tree to tree, with the least remote and largest trees providing much higher returns for effort (e.g. involving cutting, digging, local transport – often carried by hand or on horse for most of the distance back to the village – and de-sapping). Individual large trees can provide exceptional returns for effort; for example, TTC Fiji bought one yasi tree from near Seqqaqa (60 cm diameter at breast height and tall, estimated to be 120 years old) for FJD 50 000 (USD 27 000) in 2003. For a small to medium-sized tree with 20 kg of heartwood, it takes one person about one day to cut and dig up roots and another 1–2 days to de-sap and transport the wood back to the village. It would be mutually beneficial to improve communication between yasi tree owners and buyers to provide greater clarity on buyer preferences for type and choice of de-sapping, length of heartwood and other attributes. The main risk is the cutting of immature yasi by inexperienced or poorly informed landowners, sometimes encouraged by unscrupulous or poorly informed middlemen/buyers, which is an expensive waste of labour and diminishes future returns. The theft of yasi trees is an additional significant risk, especially when wild stands and plantations are remote.

*Local buyers/processors.* These actors advance finance for middlemen to scout out yasi in rural areas, later returning to procure de-sapped yasi and then transport heartwood to distilleries. The middlemen/buyers verify that the procured product is indeed yasi, steam-distil the oils, rectify oil as needed, and market the oil internationally. The main costs to local processors are payments to middlemen/buyers, including finance to buy yasi; and the costs associated with

the distillation and marketing of the essential oil. Local processors (including their buyers) receive approximately 25–50% of the price paid by the final customer, but the proportion can be higher when individual trees or large logs are auctioned on the internet. MinFor is endeavouring to regulate and control the activities of middlemen because, in some cases, their activities substantially reduce returns to tree owners. A larger issue for the government is to guarantee ownership through regulated chain-of-custody regimes and ensure legality, which is the foundation for ethical and lasting trade. There is a risk that inexperienced sandalwood buyers and middlemen will procure immature yasi or the wood of other species (believing it to be yasi), or pay too high a price for inferior wood. There are also processing risks, in which inexperienced local processors fail to distil high-quality santalols-rich oil or require high inputs, especially energy (given that distillation can take up to 72 h), such that the cost of producing oil is greater than the value of the oil, with the latter influenced by oil yield and quality. Domestic production of yasi oil was limited between 1984 and 2018, making it unviable to develop specific products incorporating yasi oil.

*International buyers and exporters.* Buy yasi heartwood in the village, sort the yasi grades and market internationally. The main costs for international buyers and exporters are associated with product inspection, the purchase of yasi heartwood, and transport from sandalwood-producing areas/villages. The costs involved in marketing and export must be borne by the parental company (e.g. based in Taiwan Province of China or Vanuatu). Whenever yasi is in scant supply, there is a risk that poor-quality or false sandalwood products will be concealed within consignments.

*International processors.* Value-adding to yasi heartwood takes place outside Fiji via the distillation of oil and its incorporation into perfumes, attars and body-care products, as well as comminution into powder for use in incense sticks. Yasi oil and powder have mainly been used as a direct substitute for East Indian sandalwood oil. The proportion of cost of the yasi component in final products is highly variable depending on the product and rate of incorporation.

*Retailers.* Provide retail outlets where consumers can access pieces of yasi heartwood, including carved items, and value-added products containing yasi heartwood powder or oil, such as perfumes and soaps (but, traditionally, yasi has not been differentiated from *S. album*). The markup on

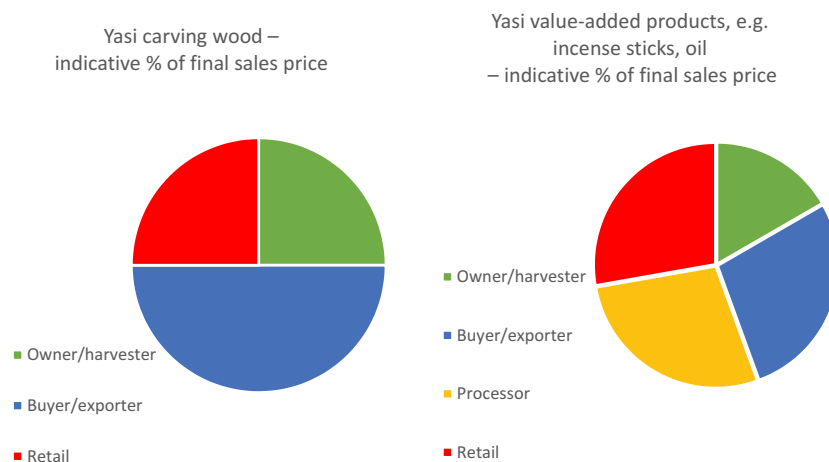


Figure 2. Indicative proportions of the final sales price received by different actors in the Fiji yasi value chain

sandalwood products is highly variable depending on location and the retailer's overheads, with sandalwood and its derived/value-added products sold into many markets (including local markets, department stores and on the internet). Retailers bear limited risks because sandalwood products are in high demand and of low perishability. Inexperienced retailers may be sold products with adulterated sandalwood oil or a synthetic mimic.

#### Step 4: assessing the market

This step in the analysis entails identifying what buyers and consumers care about and how the value chain is performing in meeting buyer and consumer preferences and demands, assessing the most important factors for buyers and consumers.

**Heartwood composition.** Heartwood oil yield is the most important criterion for most sandalwood end uses, including oil distillation and use in incense sticks. The percentage yield of oil can range from <1% to 8%, which has an enormous impact on the viability of oil distillation. Oil quality is an equally important trait for sandalwood buyers, processors and consumers, with the most highly desired oils meeting the International Organization for Standardization (ISO) standard for East Indian sandalwood oil (ISO 2002–3518) of 41–55%  $\alpha$ -santalol and 16–24%  $\beta$ -santalols. Two studies on oil constituents (Doran et al. 2005; Bush, Brophy et al. 2020) have indicated that pure yasi may be particularly rich in  $\beta$ -santalol, with individual tree samples frequently exceeding the ISO *S. album* standard. According to one French perfume chemist, the quality of a sandalwood oil for perfume may be enhanced by its minor fragrant constituents as much as by its  $\alpha$ - and  $\beta$ -santalol content and also negatively affected by undesirable minor constituents, which may give 'off-characteristics' to fragrance, give rise to allergic responses such as contact dermatitis, or are listed as undesirable in product pharmacopeia. The presence of adulterants will considerably downgrade the value of sandalwood oil and can even make it unsaleable, as will the presence of unacceptably high levels of E,E-farnesol (a skin allergen recognised by the Scientific Committee on Consumer Safety of the European Commission). Some samples of yasi essential oil have a moderate level of farnesol (1%) that may preclude their use in non-allergenic fragrances and body-care products, depending on the dilution rate. It would be useful to produce an official monograph with information on yasi oil, make this available to international buyers and end users, and use it to develop a separate standard for yasi oil. Although some sandalwood industry experts are concerned about hybrid oil quality, research indicates that *S. album*  $\times$  *S. yasi* produces a high-quality oil (Doran et al. 2005; Bush, Brophy et al. 2020). Some sandalwood traders believe that it will be in the interests of Fijian and Tongan growers to keep local *S. yasi* as pure as possible to develop niche markets, a strategy that will have positive outcomes for the conservation of the species (Bush, Thomson et al. 2020) and is also being pursued for *S. austrocaledonicum* in Vanuatu (Page et al. 2020).

**Mislabelling of exported sandalwood from Fiji.** Sandalwood buyers expect that yasi products from Fiji are derived from the pure species, although hybrids of *S. yasi* and *S. album* will produce a similar and almost indistinguishable heartwood for most users. Other Fijian trees that produce a fragrant heartwood, such as cevua (*Vavaea* spp.), should never to be substituted for yasi because this could seriously downgrade the future markets for and value of all sandalwood supplied from Fiji. Between 2012 and 2018, less than half the wood exported under the name 'sandalwood' from Fiji was *S. yasi* (or *S. yasi* hybrids): 20% was of another *Santalum* species (*S. austrocaledonicum*), which had been imported from Vanuatu for re-export, 21% was *Vavaea* spp., and 13% was *Exocarpus vitiensis* A.C.Sm. (*Cevua*). *Exocarpus vitiensis* has minor value as a fragrant timber export but should not be allowed to be exported as sandalwood (Table 1).

**For carving and furniture wood: straightness, diameter and proportion of heartwood.** The highest-value markets for sandalwood, including yasi, are the carving markets in East and South Asia and furniture market in the Middle East. In these markets, the heartwood oil composition and yield are less important than piece size, shape and figure. The preferred carving pieces are large and fairly straight and have a very high proportion of heartwood.

**Sustainability of production.** This attribute has increased in importance in recent times, especially for the sandalwood-oil and body-care-product markets. For these value-added products, especially high-end perfumes, the continued availability of consistent raw product is a prerequisite for new product development and marketing.

**Certification—legally sourced, fair trade and organic.** Some segments of international sandalwood-product markets, such as the manufacturers and consumers of high-value perfumes and body-care products in Europe and North America, are increasingly conscious of buying only from legally sourced sandalwood sources, with a preference for products that are certified as organic or fair trade.

#### Step 5: assessing strengths and weaknesses along the chain and identifying ways to take advantage of strengths and minimise weaknesses

This step in the VCA involves an analysis of strengths, weaknesses, opportunities and threats for the various actors in the value chain and the actions needed to improve its functioning. The actors are: yasi tree owners; local growers, buyers and processors; international traders; international competition; overseas processors and users; MinFor (Fiji); and retailers (see Appendix Table 1).

#### Step 6: developing a plan to improve the value chain

The final step in the VCA is to develop both short- and long-term plans to improve the functioning of the value chain by its various actors, including yasi tree owners; sandalwood

**Table 1.** Exports of sandalwood (kg) from Fiji from 2012 to 2018 (Source: Ministry of Forestry, Fiji)

Species	Export year							Total	%
	2012	2013	2014	2015	2016	2017	2018		
<i>Santalum yasi</i>	20 544	9168	401	768	321	2950	4858	39 010	47
<i>S. austrocaledonicum</i>	2	9314	500	2406		3115	948	16 285	20
<i>Vavaea</i> spp.		450	16 907					17 357	21
<i>Exocarpus vitiensis</i>	2318		8368					10 686	13
Total	24 876	20 945	28 190	5189	2337	8082	7824	83 338	

smallholder growers; MinFor (Fiji); sandalwood buyers; and sandalwood processors and users (Appendix Table 2).

## Discussion

The heartwood of *S. yasi* has considerable but currently underdeveloped potential to provide sustainable long-term income for smallholders in Fiji. It is an especially valuable commodity for remote communities, where shipping and transport costs make the trading of most fresh agricultural and fishery products unprofitable. However, realising this potential will require much greater collaboration and the sharing of relevant information and benefits among all those involved in the yasi value chain. A more functional value chain will benefit yasi owners, smallholder growers, processors and those involved in value-adding and marketing, as well as the Fiji Government and general population through increased employment and export revenue. The current sharing of the proceeds from the sale of yasi products with producers (i.e. tree owners, harvesters and growers), estimated at 20–25% of final retail prices, appears similar or better than for many other Pacific crops. Stability – or an increase – in the yasi heartwood price paid to Fiji growers and producers will send a strong market signal, thereby encouraging greater involvement in yasi growing, processing and marketing and generating long-term returns for the Fijian economy, with strong benefits at the household level for smallholders.

The yasi value chain involves tree owners, harvesters, middlemen/buyers/local processors, international buyers/exporters/processors and end-consumers, as well as supporting actors, notably regulating agencies (TLTB, MinFor) and those involved in transport/supply-chain logistics. Given the long period (20–40 years) between the planting/regeneration of yasi and its harvest, and episodic intense harvesting, there has been a lack of continuity of knowledge and relationships among actors in the yasi value chain. Historically, this turnover of actors, an associated lack of goodwill and lack of interest in building trust, a loss of *i-Taukei*/yasi tree owner collective memory, and misunderstandings of what is required by yasi buyers/markets, has diminished the functioning, worth and reputation of the yasi value chain in Fiji. There is a clear need for the Government of Fiji, through MinFor, to become more involved in the yasi value chain. Through greater education, R&D, extension, industry planning and regulation, MinFor can intervene to help realise yasi's potential to improve the livelihoods of Fijian rural smallholders. Although competition among and between yasi buyers and processors is a laudable objective, excessive competition can be counterproductive; the industry plan, therefore, needs to be carefully and appropriately calibrated to maximise the value of Fiji's relatively modest and limited sandalwood resource.

*Santalum yasi* produces a high-quality heartwood oil that, at the individual tree level, frequently meets the international standard for East Indian sandalwood. It therefore competes well in the international marketplace, but product recognition suffers because it is often tacitly substituted for *S. album*. This substitution reduces the market presence of yasi and the potential to develop unique high-value branding for yasi oil and products. Such branding will become more important as lower-grade *S. album* from overseas industrial plantations becomes more prominent in the marketplace. If Quintis and

other large-scale *S. album* plantation owners in northern Australia continue with their current harvesting schedules, there will likely be an oversupply of *S. album* oil in the market by 2022, assuming demand remains stable. This is likely to put downward pressure on prices. The current price for plantation *S. album* oil in volume is around USD 2500 kg<sup>-1</sup>. Industry insiders expect this to drop below USD 1800 kg<sup>-1</sup> by 2022, and it is possible that it will fall as low as USD 1200 kg<sup>-1</sup>. However, a more stable supply from these larger sources of high-quality sandalwood oil could stimulate market growth and opportunities to develop high-value niche products, including yasi.

*Santalum yasi* appears to have a higher proportion of  $\beta$ -santalol in its oil than *S. album* (Doran et al. 2005; Bush, Brophy et al. 2020). As  $\beta$ -santalol is chiefly responsible for some of sandalwood's signature aromas (Baldovini et al. 2011), this trait may be used to positively differentiate the product. To this end, additional research to confirm the higher  $\beta$ -santalol content is required, followed by development of a specific ISO standard for *S. yasi*, as is being done for *S. austrocaledonicum* (Dowell Forthcoming 2021). It is also possible that the Australian product will have the effect of commoditising East Indian sandalwood and its products, possibly leading to overall market growth. The yasi brand can be built on market perceptions of its exotic Pacific provenance, competitive advantages related to fragrance quality (especially its high  $\beta$ -santalol content), market-perceived and actual natural and organic production methods, and the benefits that accrue to indigenous Fijian (and Tongan) producers.

Given the evolving global market conditions for sandalwood oil in the next few years, it is risky to attempt to produce oil from yasi in Fiji in the immediate future (and certainly before local yasi plantings mature). In the future, if Fiji proceeds with yasi oil production, this will be best undertaken through either a cooperative or a 'single desk' operator. It is highly desirable that any future domestic yasi oil processor has in place a firm contract to supply an end-user and a promotional 'story' highlighting that it is *S. yasi* oil—not *S. album* or their hybrids. The branding story can be extremely positive, promoting only *S. yasi* oil and products.

The development of a yasi market presence and branding requires cooperation and coordination among all supply-chain actors.

Key challenges include the need to:

- reduce or eliminate the harvesting of immature trees by landowners and growers (tree owners/harvesters, local buyers/processors, and government);
- eliminate the substitution of yasi with inferior wood such as *Vavaea* and *Exocarpus* through education and by developing alternative markets for the substitutes (tree owners/harvesters, local buyer/processors and government);
- quantify current and future yasi resources to permit business investment (tree owners/harvesters and government); and
- develop options for aggregating legal supply for sale to international buyers (all actors).

## Conclusions

Given its high value and non-perishability, yasi has major and near-unique potential to contribute cash income to Fijian

communities in remote island archipelagos. Fiji is well placed to develop a highly competitive, sustainable yasi sandalwood industry that delivers greater returns to yasi owners, growers and processors through the development of high-quality plantings, a yasi branding strategy, the development of local value-adding and cooperation with major perfume houses and body-care-product companies.

This study identified the following ten important actions to enhance Fiji's yasi industry and improve the functioning and equity of the value chain:

- (1) Undertake enrichment planting of yasi throughout natural stands, including to increase seed sources and manage the natural regeneration of yasi by pruning and thinning neighbouring trees to increase sunlight and thereby shorten time to seed production and harvest and increase the volume and quality of heartwood from native stands.
- (2) Focus yasi extension activities on outer islands, including the Lau Group, Rotuma, the Lomaiviti Group and islands off the north coast of Vanua Levu, where villagers have few other viable commercial cash-generating crops.
- (3) Use geographic positioning systems and measure and tag (using microchips or other durable tags) sandalwood trees that are >10 cm diameter at ground level to improve the protection and management of the resource.
- (4) Develop and implement yasi sandalwood harvesting regulations.
- (5) Better plan yasi harvesting, both on an annual and a longer-term basis—led by MinFor in collaboration with yasi tree owners and growers, TLTB and sandalwood buyers.
- (6) Establish better-designed agroforestry plantings using high-quality pure *S. yasi* germplasm.
- (7) Ensure that only mature yasi, with a satisfactory proportion of heartwood, is harvested, appropriately branded and exported, and that there is no substitution of yasi with wood of other genera and species.
- (8) Develop and promote Fiji yasi sandalwood products with a unique and distinctive brand.
- (9) Provide growers and processors with feedback on the type and quality of yasi products being demanded in the international market.
- (10) Develop a yasi industry plan and national sandalwood industry association. These activities, which should be carried out under the responsibility of MinFor, should be done in close collaboration with all stakeholders to promote the orderly development of the industry, including quality assurance standards, certification and a yasi brand, and to ensure that local processing capacity matches the quantities of yasi heartwood available for processing.

## Acknowledgements

The authors gratefully acknowledge the assistance of the Fiji Ministry of Forestry and numerous informants in Fiji and elsewhere, especially Mr JJ Yu (Taiwan Timber Co. (Fiji) Ltd), and Mr Kuo Ping Ku (Taiwan Pine Cedar Wood Enterprise), as well as international and Pacific sandalwood experts (Dr Tony Page, Dr John Doran, Mr Tim Coakley, Mr Mario Di Lallo, Dr Daniel Joulain and Mr Jonathon Naupa), Mr Graham Wilkinson and two anonymous reviewers for excellent suggestions. We acknowledge

funding support from the Australian Centre for International Agricultural Research for this collaboration between the Pacific Agribusiness Research in Development 2 (AGB-2014-057) and Domestication and Breeding of Sandalwood in Fiji and Tonga (FST/2016/158) projects.

## Disclosure statement

The communicating author is a scientific advisor and shareholder in Pacific Reforestation (Fiji) Ltd, which has small-scale plantings of *Santalum* in Fiji.

## Funding

This work was supported by the Australian Centre for International Agricultural Research [PARDI2].

## ORCID

L. A. J. Thomson  <http://orcid.org/0000-0002-2984-0711>  
D. Bush  <http://orcid.org/0000-0002-8113-0231>

## References

- Baldovini N, Delasalle C, Joulain D. 2011. Phytochemistry of the heartwood from fragrant *Santalum* species: a review. *Flavour and Fragrance Journal*. 26:7–26. doi:10.1002/ffj.2025.
- Bolatolu W, Lesubula M, Vukialau M. **Forthcoming 2021**. Sandalwood development in Fiji. In: Page T, Meadows J, editors. *Sandalwood Regional Forum*; 2019. Port Vila, Vanuatu. Canberra (Australia): Australian Centre for International Agricultural Research.
- Bulai PB. 1995. Sandalwood in Fiji. In: Gjerum L, Fox JED, Ehrhart Y, editors. *Sandalwood Seed, Nursery and Plantation Technology – Proceedings of Regional Workshop for the Pacific Island Countries*; 1994 Aug 1–11; Noumea, New Caledonia. Suva (Fiji): United Nations Development Programme/Food and Agricultural Organization South Pacific Forestry Development Programme (RAS/92/316); p. 167–172. Field Document no 8.
- Bulai PB. 2007. Research, development and tree improvement of sandalwood in Fiji. In: Thomson LAJ, Bulai S, Wilikibau B, editors. *Proceedings of the Regional Workshop on Sandalwood Research, Development and Extension in the Pacific Islands*; 2005 Nov 28–Dec 1; Nadi, Fiji. Suva (Fiji): Secretariat of the Pacific Community/Australian Agency for International Development Assistance/German Agency for Technical Cooperation; p. 27–33.
- Bush D, Brophy J, Bolatolu W, Dutt S, Hamani S, Doran J, Thomson L. 2020. Oil yield and composition of young *Santalum yasi* in Fiji and Tonga. *Australian Forestry*. 83(4):238–244.
- Bush D, Thomson L, Bolatolu W, Dutt S, Hamani S, Likiafu H, Mateboto J, Tauraga J, Young E. 2020. Domestication provides the key to conservation of *Santalum yasi* – a threatened Pacific sandalwood. *Australian Forestry*. 83(4):186–194.
- Dayal B. 2012. Fiji Country Report. In: Thomson LAJ, Padolina C, Sami R, Prasad V, Doran JC, editors. *Sandalwood Resource Development, Research and Trade in the Pacific and Asia Region – Proceedings of the Regional Workshop*; 2010 Nov 22–25; Port Vila, Vanuatu. Suva (Fiji): EU-FACT/Secretariat of the Pacific Community/James Cook University/Australian Centre for International Agricultural Research; p. 9–19.
- Dhanya B, Viswanath S, Purushothman S. 2010. Sandal (*Santalum album* L.) conservation in southern India: a review of policies and their impacts. *Journal of Tropical Agriculture*. 48(1–2):1–10.
- Done C. 2007. Development of the Indian sandalwood industry on the Ord River Irrigation Area. In: Thomson LAJ, Bulai S, Wilikibau B, editors. *Proceedings of the Regional Workshop on Sandalwood Research, Development and Extension in the Pacific Islands*; 2005 Nov 28–Dec 1; Nadi, Fiji. Suva (Fiji): Secretariat of the Pacific Community, Australian Agency for International Development Assistance/German Agency for Technical Cooperation; p. 93–99.
- Doran J, Thomson L, Brophy J, Goldsack B, Bulai P, Faka'osi T, Mokoia T. 2005. Variation in heartwood oil composition of young sandalwood trees in the south Pacific (*Santalum yasi*, *S. album* and F1 hybrids in Fiji, and *S. yasi* in Tonga and Niue). *Sandalwood Research Newsletter*. 20:3–7.



- Dowell A. **Forthcoming 2021**. Essential oil of *Santalum austrocaledonicum*: developing an international standard. In: Page T, Meadows J, editors. Sandalwood Regional Forum; 2019. Port Vila, Vanuatu. Canberra (Australia): Australian Centre for International Agricultural Research.
- ISO. **2002**. 3518:2002(E) Oil of sandalwood (*Santalum album* L.). Geneva (Switzerland): International Organization for Standardization.
- Jiko L. **1993**. Status and current interest in sandalwood in Fiji. In: McKinnell F, editor. Sandalwood in the Pacific Region. Proceedings of a Symposium, 17th Pacific Science Congress; 1991 Jun 2; Honolulu, Hawaii. Canberra (Australia): Australian Centre for International Agricultural Research; p. 13–18. ACIAR Proceedings 49.
- Macgregor A, Stice K. **2014**. Agricultural value chain guide for the Pacific Islands – making value chain analysis a useful tool in the hands of farmers, traders and policy makers. Suva (Fiji): Koko Siga Pacific and CTA. [accessed 2020 Oct 31]. Available from: <https://pafpnet.spc.int/attachments/article/504/Agricultural%20Value%20Chain%20Guide%20for%20the%20Pacific%20Islands.pdf>
- Motuliki P. **Forthcoming 2021**. Tonga sandalwood. In: Page T, Meadows J, editors. Sandalwood Regional Forum; 2019. Port Vila, Vanuatu. Canberra (Australia): Australian Centre for International Agricultural Research.
- Page T, Doran J, Tungon J, Tabi M. **2020**. Participatory domestication strategy for *Santalum austrocaledonicum* in Vanuatu. *Australian Forestry*. 83(4):216–228.
- Page T, Tate H, Bunt C, Potrawiaka A, Berry A. **2012**. Opportunities for the smallholder sandalwood industry in Vanuatu. Canberra (Australia): Australian Centre for International Agricultural Research. ACIAR Technical Reports No. 79.
- Shineberg D. **1967**. They came for sandalwood: a study of the sandalwood trade in the South-West Pacific, 1830–1865. Melbourne (Australia): Melbourne University Press.
- Subasinghe SMCUP, Nawarathne BS, Rohana HK, Hettiarachchi DS. **2013**. *Santalum album* L. Current status and research in Sri Lanka. In: Nageswara-Rao M, Soneji JR, Harbaugh-Reynaud DT, editors. International Sandalwood Foundation. Proceedings of the International Sandalwood Symposium; 2012 Oct 21–24; Honolulu, Hawaii. Raleigh (NC): Lulu Press; p. 93–103.
- Thomson LAJ. **2006**. *Santalum austrocaledonicum* and *S. yasi* (sandalwood). In: Elevitch CR, editor. Traditional trees of Pacific Islands – their culture, environment, and use. Honolulu (HI): Permanent Agricultural Resources; p. 675–694.
- Thomson LAJ. **2013**. Update on sandalwood resources and trade in the South Pacific. In: Nageswara-Rao M, Soneji JR, Harbaugh-Reynaud DT, editors. International Sandalwood Foundation. Proceedings of the International Sandalwood Symposium; 2012 Oct 21–24; Honolulu, Hawaii. Raleigh (NC): Lulu Press; p. 1–20.
- Thomson LAJ. **2020**. Looking ahead – global sandalwood production and markets in 2040, and implications for Pacific Islands producers. *Australian Forestry*. 83(4):245–254.

**Appendix Table 1.** SWOT analysis for the various actors in the yasi value chain and actions needed to improve its functioning

Actor	Strengths and opportunities	Weaknesses and threats	Action needed
Yasi tree owners	<ul style="list-style-type: none"> <li>• <i>I-Taukei mataqali</i> (Fijian landowning clans) own and control the <i>Santalum yasi</i> trees on their land</li> <li>• Owners are those involved in its harvest and sale, which provides a greater level of interest in yasi trees and their protection</li> <li>• Wide dispersal of benefits from yasi utilisation among owners and their families (who may undertake de-sapping in village)</li> <li>• Low production costs cf. large-scale Australian growers of <i>Santalum album</i> (1) primarily organic methods of production, (2) niche, cottage, tribal, fair trade, marketing with associated livelihood story opportunities and (3) sustainable agroforestry production</li> </ul>	<ul style="list-style-type: none"> <li>• Unequal access to extension services, yasi and host seedlings</li> <li>• Roots and offcuts with heartwood may go unutilised</li> <li>• Lack of awareness of quality grades and no payment for quality</li> <li>• Limited awareness of the economic merits of utilising high-quality genetic stock and of growing yasi onto larger sizes with a higher proportion of heartwood</li> <li>• Lack of awareness of techniques to manage yasi regeneration to increase survival and growth rates, and imperative of proper hosting regimes to grow yasi commercially in agroforestry and home gardens</li> <li>• Premature harvesting of yasi (with loss of future income)</li> <li>• Harvesting other genera/species, which is being passed off and/or exported as yasi</li> <li>• Inability of smallholders to see the benefits of long-term investment as high returns and secure income</li> <li>• Yasi owners, in need of urgent cash or ill-informed, sometimes paid below market prices</li> </ul>	<ul style="list-style-type: none"> <li>• Better extension and education of yasi growers and owners on growing and managing yasi (need for quality germplasm and hosting regimes)</li> <li>• Development of local industry to process sandalwood offcuts into powder for use by incense manufacturers in Asia</li> <li>• Development of standardised grading system for yasi made available to tree owners</li> <li>• Better collaboration and efforts among tree owners to ensure legality of all harvested yasi</li> <li>• Investigate development of separate markets for other aromatic woods such as <i>Vavaea</i> spp.</li> </ul>
Local growers, buyers and processors	<ul style="list-style-type: none"> <li>• Oil extracted from <i>S. yasi</i> meets the ISO standards for <i>S. album</i> oil</li> <li>• While <i>S. yasi</i> trees produce acceptable heartwood at 17–20 years, the best-quality heartwood is produced on trees that are 25 years or older, giving smallholder growers the opportunity to grow trees for longer cf. private companies</li> <li>• Opportunity for lower-value sandalwood to be graded and chipped at a central point for greater utilisation of the tree: desirable to grind the chip into 10–12 mm pieces for marketing into incense markets</li> <li>• Increase economic and employment benefits from yasi industry to Fiji from expanded downstream processing</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of transparency and poor knowledge of market chain dynamics</li> <li>• Local processing industry has limited knowledge of best practice for buying yasi heartwood and distilling oil, and an incomplete understanding of sandalwood uses, consumers and markets</li> <li>• Corrupted supply chains result in poor product quality supplied, product substitution and undersupply</li> <li>• Unaware/unresponsive to the need for legality</li> <li>• It is too expensive to set up powder processing for the lower-value parts of the tree (plus fire risk if not done carefully)</li> </ul>	<ul style="list-style-type: none"> <li>• Educate local buyers and processors on the size and traits of sandalwood that indicate the tree is ready to be harvested</li> <li>• Link local buyers and processors to major markets and buyers of sandalwood and develop a better understanding of the global marketplace and threats (from other sandalwood-producing regions and synthetics)</li> <li>• Government and local stakeholders consider modes of aggregating supply to address issues of chain of custody and transparency, product legality and the international marketing for yasi</li> <li>• Improve branding of yasi as a high-value indigenous species that provides livelihood benefits for local landowners</li> <li>• Investigate establishment of a national sandalwood industry association that might develop quality assurance, certification and brand in order to generate higher prices</li> </ul>
International traders (buyers and exporters)	<ul style="list-style-type: none"> <li>• Knowledge of global sandalwood industry and markets, including how to grade yasi to maximise its value</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of commitment to development of a competitive and sustainable yasi industry in Fiji</li> <li>• Driven by commercial imperative to make short-term profits by maximising exploitation of the resource</li> </ul>	<ul style="list-style-type: none"> <li>• Better regulate and monitor activities of yasi buyers</li> <li>• Involve buyers in replanting yasi to replace harvested trees (e.g. five seedlings planted and maintained for every tree harvested)</li> <li>• Re-establish the yasi reforestation levy with funds directed to the Sandalwood Development Project and/or local communities</li> </ul>

(Continued)

Appendix Table 1. (Continued).

Actor	Strengths and opportunities	Weaknesses and threats	Action needed
International competition (growers and processors of high-quality sandalwood)	<ul style="list-style-type: none"> <li>Key strengths for northern Australia sandalwood (<i>S. album</i>) MIS producers are access to large areas of suitable (irrigated) freehold land for sandalwood culture, and established links (including supply contracts) with major global users of sandalwood oil (including United States-based Young Living, the largest essential oil company in the world, French perfumers, Nestle subsidiary and Lush Cosmetics)</li> </ul>	<ul style="list-style-type: none"> <li>The quality of oil produced from young industrial sandalwood (<i>S. album</i>) plantations is lower than that of wild-harvested sandalwood</li> <li>Due to the cost of maintaining industrial <i>S. album</i> plantations, it is not cost-effective to maintain longer rotations (up to 30 years) and therefore the future of sandalwood MIS in northern Australia is unclear</li> <li>Heartwood in young <i>S. album</i> is limited in the roots/butt to 1–2 m of trunk and the sapwood generally comprises up to 70–80% of the log. MIS companies are including secondary heartwood, which has lower oil content and is also less desired for carving logs</li> <li>Without continuity of supply of <i>S. album</i> at scale, there is limited prospect for yasi to take advantage of its niche marketing opportunity</li> </ul>	<ul style="list-style-type: none"> <li>Differentiate, through effective branding and marketing, <i>S. yasi</i> oil and products from plantation <i>S. album</i> oil and body-care products</li> <li>Accent on quality and reliability requires regulation of harvesting, especially preventing harvest of younger material with under-developed heartwood</li> <li>Substitution of non-sandalwood aromatics for yasi must be stopped</li> <li>Cooperation among Government and local industry stakeholders is needed to improve local supply-chain transparency, product legality and supply aggregation to access international markets that value sustainability/niche/organic/quality aspects of essential oil products</li> </ul>
Overseas processors and users of yasi as ingredient	<ul style="list-style-type: none"> <li>Understanding of sandalwood products markets and consumer preferences</li> <li>Opportunity to substitute <i>S. yasi</i> for <i>S. album</i> (but loss of identity of Fiji product)</li> <li>Wild <i>S. album</i> is continually reducing and rapidly being replaced by plantation <i>S. album</i></li> </ul>	<ul style="list-style-type: none"> <li>As above</li> <li>The end markets for sandalwood timber in Asia and the Middle East cannot differentiate between <i>S. yasi</i> and <i>S. album</i>. Therefore, <i>S. yasi</i> is primarily sold as <i>S. album</i> at 'album' prices. This reduces the prospects for differentiating and branding <i>S. yasi</i></li> <li>Logs coming from short-rotation industrial <i>S. album</i> plantations (approx. 15 years old) differ from wild-harvested <i>S. album</i> in proportion and quality of heartwood</li> </ul>	<ul style="list-style-type: none"> <li>Education and marketing campaign by centralised marketing body to make overseas processors and users aware of yasi and its oil properties</li> <li>Opportunity for yasi to be branded and to gain recognition in the marketplace</li> <li>Fiji Government and industry stakeholders need to consider ways to limit <i>S. yasi</i> being used as an <i>S. album</i> substitute. Log physical branding and associated market awareness</li> </ul>
Ministry of Forestry (Fiji)	<p>Mandate to regulate sandalwood development and trade in Fiji</p> <ul style="list-style-type: none"> <li>Involved in yasi R&amp;D since mid-1990s to conserve, improve and better utilise yasi</li> <li>Implementing a sandalwood development project to increase the amount and quality of sandalwood planting</li> </ul>	<ul style="list-style-type: none"> <li>Weak regulatory function and inadequate legislation to protect and advance the yasi industry in Fiji</li> </ul>	<ul style="list-style-type: none"> <li>New legislation and increased training and funding of Ministry of Forestry, including for R&amp;D, sandalwood development project, policy development, and enhanced regulatory functions</li> </ul>
Retailers of yasi products in overseas markets	<ul style="list-style-type: none"> <li>Understanding of sandalwood product markets and consumer preferences</li> <li>Opportunity to niche market yasi and/or substitute <i>S. yasi</i> for <i>S. album</i> (but latter with loss of identity of Fiji product)</li> </ul>	<ul style="list-style-type: none"> <li>Major threat from cheaper sources of plantation <i>S. album</i> oil</li> <li>Consumers have few avenues for accessing reliable independent information regarding yasi as a sustainable/niche/organic/quality product</li> </ul>	<ul style="list-style-type: none"> <li>Education and marketing campaign to make overseas sandalwood processors, users and consumers more aware of yasi and the attributes and high quality of its essential oil</li> </ul>

MIS = managed investment scheme.

**Appendix Table 2.** Short- and longer-term plans needed to improve the functioning of the yasi value chain

Actor	Short-term plans	Longer-term plans
<i>i-Taukei</i> yasi tree owners	<ul style="list-style-type: none"> <li>• Locate and map sandalwood regeneration—undertake measures to protect sandalwood, especially from fire and theft. Undertake thinning and reduce canopy cover of neighbouring trees to allow more sunlight to reach yasi</li> <li>• Protect (<i>tabu</i>) scattered mature yasi seed trees from harvest to ensure future natural regeneration</li> </ul>	<ul style="list-style-type: none"> <li>• Plant more yasi throughout natural stands, including to increase seed sources</li> <li>• Using geographic positioning systems, measure and tag (microchip or other durable tag) sandalwood that is &gt;10 cm diameter at ground level</li> <li>• Better plan yasi utilisation, together with iTaukei Land Trust Board, Ministry of Forestry and sandalwood buyers</li> </ul>
Sandalwood smallholder growers	<ul style="list-style-type: none"> <li>• Thin overstocked yasi plantings and infill-plant with recommended short-, intermediate- and longer-term hosts to improve the quality and productivity of their yasi</li> <li>• Undertake inventories of their planted stock, either by age or size (diameter at ground level). Provide information to the Ministry of Forestry to assist with planning the future utilisation and value-adding/processing of the yasi resource</li> </ul>	<ul style="list-style-type: none"> <li>• Establish better-designed agroforestry plantings using high-quality pure yasi germplasm produced by the Ministry of Forestry through ACIAR project FST/2016/158 and <i>S. album</i> x <i>S. yasi</i> hybrids in wetter areas (where yasi does not naturally occur)</li> </ul>
Ministry of Forestry (Fiji)	<ul style="list-style-type: none"> <li>• Implement yasi sandalwood harvesting regulations</li> <li>• Implement less-destructive heartwood checking procedures to avoid early tree mortality/heartwood defects when tree trunks are carelessly checked with cane knife/axe</li> <li>• Ensure that immature sandalwood is not harvested or young wild trees 'checked' with cane knife, and that other species are not substituted as yasi or sandalwood</li> <li>• Produce and distribute high-quality yasi and yasi hybrid germplasm</li> <li>• Produce and distribute yasi extension materials</li> <li>• Focus yasi extension activities on the outer islands (including Lau Group, Rotuma, Lomaiviti Group and islands off the north coast of Vanua Levu), where villagers have few other viable commercial cash-generating crops</li> </ul>	<ul style="list-style-type: none"> <li>• Develop yasi industry plan in collaboration with all stakeholders (esp. tree owners and the private sector), including canvassing options for a transparent and legal supply mechanism for aggregating and marketing yasi</li> <li>• Explore and facilitate development of a national sandalwood industry association that can contribute to the development of quality-assurance standards, certification and yasi branding</li> <li>• Publish accurate reports on the yasi resources in Fiji to facilitate private-sector investment in processing/value-adding</li> <li>• Contribute to the orderly development of the industry to ensure that excess processing equipment is not established (which will be unviable and put unsustainable harvesting pressure on both native and planted yasi resources)</li> </ul>
Sandalwood buyers	<p>Improve communication with sandalwood owners, growers and harvesters to ensure that immature sandalwood is not harvested</p> <ul style="list-style-type: none"> <li>• Encourage landowners to replant and protect some seed trees from harvest to ensure the future viability of the industry</li> </ul>	<ul style="list-style-type: none"> <li>• Provide information to landowners and growers on the size and quality of sandalwood needed (and taking into account changing market conditions and buyer preferences)</li> </ul>
Sandalwood processors	<ul style="list-style-type: none"> <li>• Make sure only mature sandalwood is harvested and brought to factories</li> <li>• Develop laboratory facilities (or link with overseas laboratories) to test their sandalwood and ensure it meets relevant standards (e.g. low E, E-farnesol, high <math>\alpha</math>- and <math>\beta</math>-santalols)</li> </ul>	<ul style="list-style-type: none"> <li>• Develop and promote Fiji yasi sandalwood products as a unique and distinctive brand (this objective may be pursued with Tongan sandalwood growers and processors)</li> <li>• Instal processing facilities that match the projected availability/supply of sandalwood resources</li> </ul>
Sandalwood exporters	<ul style="list-style-type: none"> <li>• Ensure that only genuine mature yasi heartwood is being exported</li> <li>• Undertake market research to ensure they are obtaining the highest prices for different types and grades of products</li> </ul>	<ul style="list-style-type: none"> <li>• Feedback information to growers and processors on the products being demanded in international markets (and changing demands and prices)</li> </ul>

ACIAR = Australian Centre for International Agricultural Research.