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**Australian Centre for  
International Agricultural Research**

# Final report

*project*

## **Enhancing returns from high-value agroforestry species in Vanuatu**

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This report is dedicated to the memories of two important DoF staff members Joseph Tungon (Senior Researcher) and Philemon Ala (Senior Botanist) both of whom passed away during the period of this ACIAR project. Both Joseph and Philemon made immeasurable contributions to their respective fields of expertise in Vanuatu and were valued members of several ACIAR-funded projects involving the DoF.

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## 2. Abbreviations

AAF	Australian Agroforestry Foundation
ABN	Australian Business Number
ACIAR	Australian Centre for International Agricultural Research
ACT	Australian Capital Territory
COVID	Coronavirus disease
CSIRO	Commonwealth Scientific and Industrial Research ...
CSO	Clonal Seed Orchard
DBH	Diameter at Breast Height (1.3m)
DBHOB	Diameter at Breast Height Over Bark (1.3m)
DoF / VDoF	Vanuatu Department of Forests
EoPR	End of Project Review
GC-MS	Gas Chromatography Mass Spectrometry
GSO	Grafted Seed Orchard
MALFFB	Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity
MDG / WMDG	Whitewood Market Development Group
MMA	methyl-methacrylate
MOA	Memorandum of Agreement
MTA	Material Transfer Agreement
MTG	Master TreeGrower
MTR	Mid-Term Review
NGO	Non-Government Organisation
NIS	Nut-in-Shell
PC	Participating Country
PDF	Portable Document Format
PHAMA	Pacific Horticultural and Agricultural Market Access
PNG	Papua New Guinea
SCU	Southern Cross University
SIDS	Small Island Developing States
SPA	Seed Production Area
SPC	Secretariat of the South Pacific
SPRIG	South Pacific Regional Initiative on Forest Genetic Resources
SRA	Short Research Activity
SSO	Seedling Seed Orchard
TEOS	Tetraethoxysilane
TRF	Timber Research Facility
USB	Universal Serial Bus
UniSC	University of Sunshine Coast
VAC	Vanuatu Agricultural College
VARTC	Vanuatu Agricultural Research and Training Centre
VFA	Vanuatu Foresters Association
VISA	Vanuatu Industry Sandalwood Association
VPPA	Vanuatu Primary Producers Association

### 3. Executive summary

This project further developed three key forestry species in Vanuatu namely nangai nut (*Canarium indicum*), sandalwood (*Santalum austrocaledonicum*) and whitewood (*Endospermum medullosum*). As Pacific communities' transition towards a cash-based economy, alternative and diversified sources of income are needed. All three species already have viable markets for their products and can be easily incorporated into traditional agroforestry systems in Vanuatu. Their development is a priority of the Vanuatu Department of Forests, who consider them to have great potential for smallholder production to improve livelihoods. Each species has its own unique product, history of smallholder planting, and development needs.

The aim of this project was to advance the Vanuatu planted forestry sector by improving the availability of new and existing technologies and facilitating wider smallholder adoption of the three priority species. To achieve this aim, the project sought to: (1) enhance availability of selected canarium seed through evaluation and capture of wild resources; (2) improve the value of planted sandalwood by widening the deployment of improved genetic resources; (3) enhance knowledge and capacity among whitewood value chain stakeholders, of growing, processing and marketing of high and lower value wood products; and, (4) increase adoption of existing technologies for planted forests through improved knowledge development and transfer among stakeholders. Each objective incorporated several activities to meet the stated aim.

Activities and achievements against objectives were:

#### **Canarium —**

The project characterised the morphological variation of *C. indicum* in Vanuatu to provide a profile of its potential for domestication. Data was collected in multi-year surveys across the range of the species. Significant variation was found in the key commercial trait of kernel mass. The results demonstrated correlation among fruit and nut-kernel traits suggesting that screening large numbers of trees was possible through evaluation of fruit characters. While kernel traits varied between years, trees tended to maintain their ranking among the trees in subsequent years. The results from this study have important implications for further domestication of the species to produce forms that are desirable for planting in commercial agroforestry systems. While trials were undertaken for grafting propagation of canarium (top cleft and budding) further research is required to enable routine clonal propagation. Given the modest results of vegetative propagation, the project focussed on seed collections from selected wild trees. A canarium provenance-progeny trial was established at VARTC on Santo representing 37 families selected for the high kernel mass. This trial represents an important genetic resource for the species domestication and future research. To support the ongoing development of canarium in Vanuatu the project also produced: (1) a domestication strategy to support ongoing improvements and (2) a canarium grower's manual that presents the current state of knowledge for smallholder production, processing and marketing.

#### **Sandalwood —**

A participatory domestication strategy was documented that builds upon the selection work undertaken in previous ACIAR investments. This strategy serves as a blueprint for ongoing genetic improvement of Vanuatu sandalwood, to maintain its presence in the market as a premium product. The strategy document identified key research avenues to support the species improvement and information transfer via a series of technical notes. Technical notes on grafting techniques and wood grading were published and a Materials Transfer Agreement (MTA) developed during the course of this project. Deployment of improved genetic resources was achieved through the establishment of four grafted seed orchards, and a small progeny trial from selected families with key industry participants. A report documenting these and previously established orchards was prepared to accompany the domestication strategy. Grafting training courses were convened with the

two main commercial growers to develop their capacity for clonal selection and duplication of their grafted seed orchards. The project supported specific capacity building with DoF research staff to facilitate knowledge transfer between generations of research foresters. The project made significant contribution to the publication of a 'Pacific Sandalwood Growers Manual' including country-specific recommendations for planting, marketing and host selection. This represents an important achievement and is published in ACIARs monograph series;

### **Whitewood—**

An inventory of the current plantation resource on Santo was undertaken and revealed that wood volumes available, although modest, provide a valuable opportunity for potential processors and growers. This should encourage further planting of whitewood. An updated domestication strategy was developed for whitewood encompassing the improved genetic resources of the DoF. This sets out the pathway to continue the improvements in productivity and timber quality for this nationally important timber species.

The project, through additional ACIAR financial support, facilitated the reconstruction of the Timber Research Facility (TRF) following cyclone Harold. This has culminated in its reinstatement as an important research and development facility for the DoF, which is administered by the Vanuatu Foresters Association. A visual whitewood timber grading system was developed, which sets out minimum requirements for sawn wood products from trees grown in plantations. This permits more transparent trade of planted whitewood timber on the domestic market. Research into low-cost chemical treatments of whitewood showed that CaCO<sub>3</sub> (coral) and seawater offer potential in providing affordable protection to extend the in-service durability of the timber. A design for a low-cost timber dryer was drafted and based on an insulated wood structure, fireplace and solar powered fans. It is envisaged that such a dryer will be constructed at the TRF post project. Operation of this equipment will feature in a processing manual to be prepared post project and serve as a training aid at TRF

Adding value to the grading system, preservative treatments and drying technologies, a building design was drafted to guide the use of locally grown whitewood in domestic construction. The design encompassed a single-story, cathedral ceiling, residential timber dwelling compatible with Vanuatu indigenous architectural values. A demonstration building at DoF in Santo was completed and is being used as an office having survived cyclone Harold.

### **Adoption —**

#### Extension

A review paper on agroforestry extension in Vanuatu was produced to guide the introduction of the peer-mediated Master TreeGrower (MTG) extension format. A 3-day pilot course in Port Vila preceded and informed the delivery of three full MTG courses. These courses included: (1) a canarium grower group of Ni Vanuatu women on Malo; (2) a whitewood grower group in Santo; and (3) for sandalwood growers from across the country at DoF in Tagabe. The courses were convened by Rowan Reid and, in total, engaged ten DoF extension technicians. Participant feedback prior to and following delivery of the workshops revealed substantial gain in forestry knowledge. A review of the training revealed women-only workshops, and nurturing female experts and leaders can contribute addressing issues of gender equity in access to forestry knowledge and support. A planning and strategy document based on the recommendations outlined in review reports was provided to DoF for further alignment with DoF perspectives. DoF management has viewed the program favourably for its capacity to engage growers across the value chain rather than focussing on just one aspect such as planting. DoF has plans for deploying a MTG-like forestry extension program in Vanuatu. This shows that the MTG was successful in developing extension expertise among DoF staff to independently deliver the program for a range of stakeholders.

### Communication

To develop a more compelling engagement of forestry stakeholders eleven short and one long videos were produced. These were executed through the training delivered by project-endorsed Australian volunteer Ginny Stein. These videos were deployed through social media (primarily Facebook) and proved very popular with the community. The videos and more regular engagement of DoF with social media helped to propel the number of followers from 500 in mid-2017 to over 4,000 in 2021. While a new page was necessary due to administration issues, DoF staff have maintained a continual presence with followers now back up to over 3,000. Through the training and ongoing dedication of forestry staff members, the DoF engagement with their constituents has been greatly enhanced.

### Financial analyses and value chains

The financial performance of smallholder production of the three priority crops (canarium, sandalwood, whitewood) was analysed. They show that, at the current prices, the viability of canarium and whitewood production is marginal, while the profitability of sandalwood is reduced substantially by the widespread practice of early harvesting. The challenges and opportunities for these industries discussed in the three papers associated with the analyses will inform their future development to the benefit of smallholder farmers and the national economy, as they show they can be profitable to small holders with value chain interventions and improvements. These were more fully explored in a paper for developing niche forest product value chains that are inclusive of small-scale producers in Vanuatu. The report describes the current situation with each of the three industries, and then proposes inclusive value chains (IVC) that improve on the business-as-usual scenario, while recognising the many challenges.

### **Summary —**

This ACIAR project has consolidated existing knowledge on appropriate production systems, analysed the financial performance of smallholder production systems, evaluated options for developing more inclusive supply chains and developed domestication strategies for the three focal species. Combined, these outputs represent a resource to guide the strategic development of smallholder planted forestry in Vanuatu. This project has also endeavoured to address adoption issues with smallholder growers and producers in Vanuatu and Melanesia more broadly by: publishing comprehensive grower's manuals for canarium and sandalwood; testing the effectiveness of an adapted (to the social context of Vanuatu) version of the Master TreeGrower Program as a model for an extension approach based on the principles of peer-mediated learning; and, use of short videos distributed on social media for disseminating information on tree growing.

The project has met most of its milestones despite the major constraints of travel restrictions because of COVID-19 (2020-2022) and the damage in Santo of project infrastructure and trials caused by cyclone Harold (April 2020). As well as these external limitations, DoF had staffing challenges to adequately support the implementation of the project. For DoF research to have a more focussed approach there is a need for a systematic review of the research agenda. This review would set priorities for research and establish resource needs in terms of staffing, infrastructure and financial inputs. This review would help guide the allocation of governmental resources and align externally-funded projects with their research objectives.

## 4. Background

The establishment of tree crops represents an important development opportunity for smallholder farmers in Vanuatu. Forest tree cropping has the potential for generating significantly greater local and national economic benefits than resource extraction from already depleted native forests. A planted forest can have benefits that accrue over time and contribute to mid- and long-term wealth creation, while also having environmental advantages. Economic benefits can be amplified when the trees are derived from improved germplasm, whereby they may require fewer inputs, have higher productivity and shorter rotation, as well as higher product quality as compared with wild unselected stock. The process of domestication has a long trajectory however significant short-term gains can be made by following a participatory approach to selection and deployment of improved stock.

With these considerations we sought to further the development of three key species in Vanuatu namely nangai nut (*Canarium indicum*), sandalwood (*Santalum austrocaledonicum*) and whitewood (*Endospermum medullosum*). All three species already have viable markets for their products and can be easily incorporated into traditional agroforestry systems in Vanuatu. Their development is viewed as a priority by the Vanuatu Department of Forests who consider them to have significant potential for smallholder production to improve livelihoods. Each species has its own unique product, history of smallholder planting, and their own development needs.

### Canarium

*Canarium indicum* is a nut producing species that is native to eastern Indonesia, Papua New Guinea (PNG), Solomon Islands and Vanuatu (Randall et al. 2018). The edible kernels are produced by the tree annually and have been a source of human food for thousands of years (Yen 1996). Most smallholder farmers in the region are familiar with the tree and its products and the species is well integrated into local agricultural systems (Fisher 2011).

As Pacific communities' transition towards a cash-based system, alternative and diversified sources of income are needed. Processed nuts are an ideal product for Pacific Island countries to produce as they can be transported easily, stored for long periods and do not have the cold chain challenges of other produce. There is an existing market for the nuts in the region and the tree has multi-purpose products making the species suitable for commercialisation (Evans 1996; Randall et al. 2018).

Throughout the Pacific, predominantly female smallholders in remote villages process *Canarium* using traditional methods and sell their product in central markets. Several ACIAR-funded *Canarium* projects have focused on value added processing and market development with nuts coming from village trees (Wallace et al. 2012; Wallace et al. 2016; Wallace et al. 2021). With considerable variation found in nut characteristics there is opportunity for the species' further domestication to improve the consistency and quality of the products. Significant variation has been found across a wide range of nut traits including kernel size/mass, kernel:nut ratio, number of kernels per nut, nutritional content, oil content, shell thickness and ease of cracking (Cornelius et al. 2012; Evans 1999a; Nevenimo et al. 2006; Randall et al. 2016).

To increase yield, kernel size and product consistency and address the production issues of quality, reliability and uniformity, it is necessary to formally commence domestication activities for *Canarium* in Vanuatu – including examining asexual multiplication techniques for movement and development of improved cultivated forms. Through different propagation techniques it may also be possible to produce two forms of trees: small, early-bearing fruit trees for smallholder nut production (marcotting and grafting) and taller trees suitable for agroforestry applications such as shade for cocoa and coffee plantings (seedling stock).



## **Sandalwood**

Vanuatu sandalwood, (*Santalum austrocaledonicum*), has been traded since the 1800s (Shineberg 1966) and remains a premium non-timber forest product for resource owners. The heartwood is recognised in the international marketplace having a high quality fragrance, and there are branding opportunities associated with the exotic tropical location and utilisation that represents an organic production and traditional custom (Page et al. 2018; Page et al. 2012b). In recognition of this ACIAR has made several investments into the species development and domestication (FST/2002/098 and FST/2008/010). These projects have established improved genetic resources, developed reliable methods of propagation (Tate 2015; Tate et al. 2006) and knowledge of breeding systems (Page et al. 2012a; Tamla et al. 2011). Improved genetic resources have been deployed as grafted seed orchards into areas where communities previously have had very little opportunity to plant sandalwood due to limited access to seed. Sustainable and expanded deployment of these germplasm resources is constrained by lack of government funds and support. From the outset of this project it was considered that more active industry involvement in sandalwood domestication would result in a more enduring model for improvement and deployment for smallholder growers.

Given the decline in natural sources of sandalwood and the ongoing market demand many of Vanuatu's smallholders have responded well to government initiatives to promote the planting of the tree crop among their home gardens (Bome and Kalsakau 2021). The strong international demand and ongoing supply deficit has resulted in increasing prices paid to landowners for sandalwood (Page et al. 2012b). Therefore interest in planting sandalwood for commercial purposes remains buoyant among landholders and investors alike. Page et al. (2012b) conservatively estimated that 303,000 sandalwood trees were planted between 2000 and 2006, while Davila et al. (2021) reported 100,000 seedlings were distributed throughout the country between 2008 and 2012. These figures represent both landholder driven planting and government supported seedling distribution. Therefore it is possible that at least 20,000 seedlings are distributed annually while a further 40,000 to 50,000 sandalwood seedlings are planted per year using village-based production. This annual planting rate would mean that over 1 million sandalwood trees have been planted since the first ACIAR project (FST/2002/098) commenced in 2002. Importantly, two commercial plantings have been established in the island of Efate with a combined area of approximately 250 ha. These commercial operators were considered to offer potential for the sustainable production of improved genetic resources that could be further deployed to smallholder growers through product supply agreements.

## **Whitewood**

Vanuatu was endowed with a relatively small natural forest resource compared with its regional neighbours such as the Solomon Islands and Papua New Guinea (Regenvanu et al. 1997). As such it was very sensitive to the impact of extensive logging that occurred during the 1980s and 1990s, resulting in the exhaustion of its native timber species, including whitewood and other important hardwoods (Freeman and Piper 2017). Consequently Vanuatu has since become more dependent upon imported timber for local construction (Viranamangga 2013). Smallholders without their own natural timber resource or cash income to pay for imports, are left with little option but to use non-durable timbers. This has led to a reduction in their standard of living owing to the reduction in the longevity of subsistence dwellings and a more frequent reconstruction cycle. With this in mind, this ACIAR project considered that a planted timber industry would have the potential to address localised timber shortages while also generating additional income. Whitewood (*Endospermum medullosum*) was identified early as a candidate species (Walker et al. 1996) due to its amenability to production using either conventional forestry and agroforestry processes, as well as its tolerance of cyclones (Glencross and Viranamangga 2012; Thomson et al. 2018; Tungon and Tabi 2015). With commercial interest in establishing a significant planted whitewood resource during the 1990s (Walker et al. 1996) the Department of Forests promoted its adoption among smallholders (VDoF 1997, 2010,

2012). As a modest planted resource has matured there has been a need to develop methods for efficiently utilising the resource to give growers a return on their investments (Aru et al. 2012) and provide a stimulus for further expansion of the sector (Viranamangga 2013; Viranamangga et al. 2012).

ACIAR project FST/2012/042 highlighted the need for research and development to address a range of impediments for meaningful engagement of smallholder growers and small-scale processors in the whitewood value chain. Firstly, it was necessary to quantify the extent and scale of the existing planted whitewood resource to determine potential timber flows that inform investment decisions. In the absence of such information the industry was exposed to unnecessary risk that restricts strategic planning to promote value creation and ensure long term viability. Secondly, with growers seeking early returns from their woodlots there was an obvious need for customising timber processing procedures to suit the properties of young plantation-grown whitewood including thinnings. The utilisation of young knotty wood was therefore emphasised as a product development requirement for the project to explore. Equivalent imported knotty pine products were already present in the Vanuatu market, which gave the project confidence that there was acceptance of such products among consumers. The development challenge was to identify processes that would allow young whitewood timber to match or exceed the value and performance of current imports. It was considered a research priority to facilitate a more complete economic utilisation of the resource to help growers to realise the commercial benefits from their whitewood investments.

While technical considerations of product quality and price are central to the competitiveness of whitewood in Vanuatu, additional value chain constraints were identified at the beginning of the project. Specifically, a range of stakeholders in the whitewood value chain are generally unaware of the interdependency between businesses, and the need for collaborative investment and fair profit distribution. This has resulted in a lack of coordination and ineffective communication among industry stakeholders. Prices paid for planted whitewood have been aligned with the low prices associated with native forest log harvest. Furthermore the uneven distribution of profits through the actions of the small number of preservative treatment service providers has also contributed to an inequitable value chain. This dysfunction has had a disproportionate and negative effect on the profitability of smallholder whitewood growers. This in turn discourages the investment necessary to fully develop the planted whitewood industry. The project sought to address these issues through a participatory supply chain analysis and associated reform by facilitating the formation of a multi-actor Market Development Group. This approach was considered important to build essential social capital among stakeholders and offer insight into the issues encountered by allied businesses within the value chain and the importance of interdependencies and maintaining profitability for all its members (Cousins et al. 2006; Ribeiro and Zwirner 2010; Roden and Lawson 2014; Villena et al. 2011).

In addition to the focus on commercial development of whitewood, the project sought to address the needs of growers in remote rural locations to more efficiently utilise the timber for their own construction purposes. Since whitewood is a non-durable timber, it has limited application in construction of traditional dwellings since it must be protected from weather exposure and pest degradation. To extend the serviceable life of the timber, the project identified a need to evaluate a range of smallholder-appropriate treatments applicable in remote areas. The development of such processes also permits the full utilisation of their woodlots by allowing smallholders to make subsistence productive use of utility and non-commercial grades.

## **Adoption**

With ACIAR making a series of investments in smallholder forestry in Vanuatu over the past two decades, DoF was enthusiastic to develop avenues for smallholders to access the benefits of research. With limited recurrent government budget allocated to forestry

extension activities, particularly in the more remote areas of the country, the DoF aspired to develop more sustainable models for engaging with the smallholder sector to transfer up-to-date knowledge. This project sought to examine methods for improved communication with end users through peer-mediated learning for addressing existing constraints to forestry extension. This concept recognises that peers exert a significant influence on individual adoption of new practices (Kueper et al. 2014). It acknowledges that innovations, regardless of their origin, are often diffused horizontally, via social connections. Users then modify them to suit individual circumstances (Rogers 2003). Peers may be defined as friends, habitual associates, or unfamiliar people with similar interests and/or experiences (Shiner 1999). Ma et al. (2012) proposed that such facilitated peer learning in a forestry context can be achieved by making information accessible to participants and assisting dialogue and learning among all peers. The project engaged an existing peer-based extension format known as the Master TreeGrower (Reid 2008) to adapt it to the social context of Vanuatu and determine its effectiveness for forestry extension in Vanuatu. This recognises the success of a similar roll out of the Master TreeGrower with community- and family-based planted forestry initiatives in parts of Africa and southeast Asia (Reid 2017).

In addition to the extension research conducted in this project, we also sought to evaluate the use of communication media for wider dissemination of forestry information to the target audience of smallholder growers. At the time of the project inception, it was recognised among in-country project partners that while historically radio was the main source for disseminating information across the country, particularly for those in remote locations, the emergence of social media, with Facebook in particular, was a rapidly emerging preference of engagement among people in Vanuatu (Bjornum 2016; Willans 2017). In 2017 internet penetration was at 30% increasing at an annual rate of 62% while active social media users represented 16% of the population, increasing at 63% (Kemp 2017). The most recent data shows an internet penetration at over 40% and social media users at 35% (Kemp 2022). Discussions with DoF senior personnel during the project design revealed that while departmental staff have intermittently engaged with radio media it was important to determine the effectiveness of social in promoting smallholder engagement in planted forestry and adoption of appropriate practices. Despite government concerns about the use of social media by civil servants (Singh 2015), from the outset of the project the DoF sought project support to engage more systematically and innovatively with Facebook as a way to connect with existing and potential growers and transfer information.

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## Objectives

The aim of the project was to advance the Vanuatu planted forestry sector by improving availability of new and existing technologies and facilitating wider smallholder adoption of three high-value forestry species: canarium, sandalwood and whitewood. To achieve this aim, the following objectives were proposed:

1. Enhance availability of improved quality *Canarium* seed through evaluation and capture of wild resources;
2. Improve the value of planted sandalwood by widening the deployment of improved genetic resources;
3. Enhance knowledge and capacity within whitewood value chain stakeholders, of growing, processing and marketing of high and lower value wood products;
4. Increase adoption of existing technologies for planted forests through improved knowledge development and transfer among stakeholders.



**Figure 1: Farmer field activity associated with a Master TreeGrower event in Efate.**

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## 5. Methodology

The methods proposed and/or used to deliver on each of the objectives were:

### ***Objective 1: Enhance availability of improved quality *Canarium* seed through evaluation and capture of wild resources***

#### 1.1 Characterise existing *Canarium* genetic resources by random and targeted sampling

In total, 256 trees were sampled from eight northern islands in Vanuatu. Of these, 82 trees were sampled in 2017, with two locations on Espiritu Santo (east  $n = 25$ ; south  $n = 5$ ) and one in south-west Malekula ( $n = 52$ ). The additional 175 trees included in this study were sampled in 2018 across seven islands. The locations included: north Malekula ( $n = 47$ ); Epi ( $n = 30$ ); Pentecost (central  $n = 13$ , south-west  $n = 32$ ); Malo ( $n = 10$ ); Ambrym ( $n = 20$ ); Tongoa ( $n = 12$ ) and; Paama ( $n = 10$ ). The locations and the number of trees sampled within islands were roughly based on the size of the island, accessibility of the *canarium* trees and the number of mature fruits in the crown of the tree at the time of sampling. For example, 99 trees (over two years) were included from Malekula, which is a large Island and reported to have high diversity levels (Evans 1999b), whereas less trees ( $n = 10$ ) were sampled from smaller Islands such as Paama and Malo.

Mature fruits ( $n = 50$ ) were collected from the canopy of each tree by either stoning, climbing, a bamboo pole, or using a throwing rope. Fruits were then placed in a plastic mesh bag and transported back to a central location for processing. A sample of 25 fruits from each tree were randomly selected and the morphological traits were characterised (total  $n = 6400$ ).

#### 1.2 Adapt and apply existing methods for clonal propagation of selected individuals

A total of four trials were performed to adapt the grafting (top cleft and budding) method of propagation to clonally replicate *canarium* collected from mature trees in the field. The methods of grafting included top wedge and side grafting and the methods of budding included patch and chip budding. The rootstock used were seedlings derived from the seeds collected during the field surveys in 2017 and 2018. The scions used included seedlings and mature branch material collected in 2018 and 2019.

#### 1.3 Capture selected trees by a combination of clonal and seed-based methods to establish a population for tree selection

During the surveys in 2017 and 2018 seed was collected from almost all trees characterised for germination in the nursery. It was more efficient to collect additional fruits during sampling rather than return to selected trees at a later date. Unfortunately fungal issues in the nursery at Tagabe resulted in the death of almost all seedlings and recollection was required in 2019.

The objective in 2019 was to capture the best 20% of trees (or the Top 50 from the 256 surveyed). It was not expected that all selected trees would have ripe fruit available for re-collection, and it was possible that some trees would have low germination rates, so this number was extended to the Top 75 trees. There is uncertainty as to whether single kernel fruits are more desirable than double kernel

fruits. Therefore two lists were compiled: 1) the Top 75 trees which had the largest average single kernels (excluding doubles), and 2) the Top 75 trees which had the largest overall average kernel mass per fruit (includes both single and double kernels). These two lists were combined to produce a single list of 126 trees which was then prioritised into three categories:

1. Selections which made both the single and combined kernel Top 75 list. This was further segregated into:
  - a. 72% or higher single kernels; and
  - b. 52-71% single kernels.
2. Top 50 selections from either single or combined kernel lists.
3. The remaining Top 51-75 selections from either single or combined kernel lists.

The Islands of Malo and Tongoa were removed from the list as they only had two category 3, and one category 1 and four category 3 selections, respectively. Logistically travel to these islands could not be justified and the target list was reduced to 119 selections.

Approximately 75 seeds from each of 82 selected trees were collected and were divided in half to allow a complete set of trees to be grown at DoF and VARTC nurseries in Santo. Given the previous unsuccessful attempts to raise nangai seedlings in 2017 & 2018 in Efate, the risk was split across two nurseries in Santo, a more northern location, in an attempt to better ensure success.

#### 1.4 Evaluate existing Canarium crop management methods & develop smallholder-appropriate systems

The existing crop management methods were reviewed through interviews and discussions with resource holders during the Canarium collections of 2017 to 2019. This information was synthesised into a summary report that formed the basis for further consultation with key experts and stakeholders in Vanuatu, Solomon Islands and Papua New Guinea through collaboration with ACIAR project FST/2017/038. From these consultations and feedback the summary report was further developed in combination with a review on available literature on production and processing methods. Through these additional contributions the document inclusive of local images was further developed into a monograph that would be suitable for publication and dissemination among practitioners and growers throughout PICs.

### **Objective 2: Improve the value of planted sandalwood by widening the deployment of improved genetic resources (~25%).**

#### 2.1 Develop participatory domestication strategy.

The participatory domestication strategy was developed for *S. austrocaledonicum* in consultation with both VDoF staff and industry participants. The strategy was based upon existing genetic resources both unimproved (wild and provenance collections) and already improved (clonal archive and grafted seed orchards). The approach to domestication followed a traditional recurrent selection combined with clonal capture that is implemented on a 'rolling front'; where there is no distinction

made between generations. Breeding resources and deployment of improved stock was considered through participatory means by engaging with the private sector to host trials and incorporate the germplasm into their existing plantings together with deploying to smallholder growers. The strategy calculated the likely deployment and genetic gains for the species domestication. Estimation of genetic parameters through progeny trials was emphasised as an important future development to progress the domestication of the species.

## 2.2 Establish next generation breeding resources for sandalwood.

As part of the participatory domestication grafting training was undertaken in September 2018 with 25 participants (DoF, Summit Estate and farmers from various islands) attending a two day course. Another three day training course was held in September 2019 with 17 participants (DoF, Santal Valley and Summit Estate). Both courses were convened by David Spencer, Joseph Tungon and Michael Tabi. The courses comprised a power point presentation followed by practical demonstrations with participants practising methods in the nursery. The second and third days started with revision and then all participants spent the remainder of their time refining their craft through practice combined with guidance by the convenors.

The establishment of next generation breeding resources was achieved through both seed collection and clonal replication of the clonal archive in Tagabe. Four new grafted seed orchards were established, one each at Summit Estate (Mar 2019), Tanna (Dec 2019), Santal Valley (May 2020) and Malekula (Jun 2020).

### ***Objective 3: Enhance knowledge and capacity within whitewood value chain stakeholders, of growing, processing and marketing of high and lower value wood products (~25%).***

#### 3.1 Conduct inventory of current plantation resource on Santo

The extent of planted stands has been drawn from a survey conducted in 2007 and a review of existing seedling distribution data that gives a relative indication of planting intentions. This data contains gaps where seedling distribution was not recorded or where it has since been lost. The 2007 survey of extent whitewood plantations existing at that time identified around 540 ha of whitewood plantation that had been established between 1990 and 2005. Three hundred and fifty hectares of that planting was carried out by Melcoffee sawmill at Lorum over the 1990s. The other 190 ha of community plantations existed across over 500 sites with an average plot size of 0.68ha. This historic information was used to characterise the extent of the resource, as well as informing the sampling strategy. A representative set of 40 x 0.5 ha plantation plots was established across the estate by SCU and DoF staff. These plots were measured for growth or volume, stem form, clear bole length. This was used to calculate the expected wood volumes from the smallholder planted whitewood resource.

#### 3.2 Continue to build the market for structural wood by developing methods of construction and educating builders.

A product specification was developed for whitewood which sets out the minimum requirements for visually-graded sawn-wood products recovered from trees grown in plantations in Vanuatu. The specifications are applicable to grading all sawn

timber products including timbers for decorative, small and large section structural and utility end uses.

A building design was produced to assist in the construction of a generic single-story cathedral ceiling residential timber dwelling. The design reflected The Republic of Vanuatu indigenous architecture values from locally grown whitewood plantation timber. The design document outlines key considerations based on research conducted by the Southern Cross University and The Australian/New Zealand residential building standards (National Construction Code 2019 - Building Code of Australia).

### 3.3 Evaluate the effectiveness of smallholder-appropriate technologies to improve the durability of whitewood for local-subsistence construction.

A series of whitewood timber boards were treated with locally available treatments, with replicates set inside and outside the Timber Research Facility (TRF). Also established at the TRF was a graveyard trial using inground application of whitewood rounds treated with a range of preservatives. The TRF was extensively damaged by the effects of cyclone Harold in April 2020. Much of the trial wood was recovered, however its current status still needs to be determined.

## ***Objective 4: Increase adoption of existing technologies for planted forests through improved knowledge development and transfer among stakeholders***

### 4.1 Improve accessibility of existing knowledge on plantation forestry to increase rates of adoption.

A review of existing extension services was produced in relation forestry extension. It identified key agencies and detailed their role in extension and development. The review highlighted the degree to which the outcomes of an extension program aimed at satisfying community needs will also meet the needs or interests of particular industry sectors, government agencies or conservation groups.

A Master TreeGrower pilot workshop was conducted at Farea Pasifika in Port Vila from 5-7<sup>th</sup> June 2018. The workshop was attended by 26 participants including farmers and representatives from private companies (Summit Estate, Lapita Café), NGOs (Vanuatu Teachers Union, Vanuatu Islands Sandalwood Association), Government Departments (Dept. Women's Affairs, Department of Forestry (DoF), Department of Agriculture) and educational institutions (Vanuatu Agricultural College). The workshop was convened by Rowan Reid and Anne-Marie Sarisets (DoF), with additional inputs from James Samuel, Michael Tabi (DoF) and Tony Page (USC).

The first full MTG course was conducted for a group of Ni Vanuatu women at the Avunatari Mission on Malo island from the 2<sup>nd</sup> till the 6<sup>th</sup> of October 2018. The workshop was attended by 18 participants (14 from Malo women's group and 4 BBB (Bisnis Blong Buluk) women's group) and 8 trainers. The workshop was convened by Rowan Reid, with additional inputs from Anne-Marie Sarisets, Joseph Tungon, Mesek Sethy (DoF), Norah Rihai (VAC), Marie Andre (ACIAR FST-2014-067) Elektra Grant (USC), and Votausi McKenzie (Lapita Café). The BBB women's group (ACIAR LPS-2014-037) were largely participants of the workshop, but they also contributed technical information related to financial literacy and associated bookkeeping.

The second MTG was conducted in Santo for 14 participants (10 male and 4 female) from 29<sup>th</sup> March to the 3<sup>rd</sup> April 2019. The workshop was convened by



Rowan Reid, with additional inputs from Anne-Marie Sarisets, Frank Joely, James David, Mesek Sethy and Samuel Bebe (DoF), Graeme Palmer (SCU), and Rodney Aru (Melcoffee).

The third full MTG was held at the DoF in Tagabe with field visits around the island of Efate. The workshop was attended by 56 participants, including 25 smallholder farmers, 10 commercial or joint venture producers, 3 sandalwood licensees, 2 education providers and 16 government employees. The workshop included trainers from the Department of Forests (3), Australian Agroforestry Foundation (2) and the University of the Sunshine Coast (2). The workshop was convened by Rowan Reid (AAF), Judy Kalotap (DoF) and Toufau Kalsakau (DoF), with additional inputs from Anne-Marie Sarisets (DoF), Ben Boxshall (AAF), Joseph Tungon (DoF), Liz Ota (USC) and Tony Page (USC).

#### 4.2 Build industry capacity to understand and manage key aspects of the timber industry value chain.

The Vanuatu Foresters Association (VFA) was proposed by key project stakeholders as the most appropriate organisation to operate the Timber Research Facility (TRF). The purpose of this facility is to demonstrate the viability of a vertically integrated processing operation based on plantation grown wood, encompassing sawing, seasoning, treating and marketing of timber derived from smallholder whitewood plots. The research must demonstrate that a VFA managed facility can provide good returns to growers for their whitewood, to support the expansion of the smallholder planted resource. This in turn can then support the expansion of the facility and offer scale-based production efficiencies required to remain competitive in the domestic market. The main output from this strategy is to provide a permanent market for plantation grown wood and drive ongoing plantation establishment or replanting.

#### 4.3 Develop locally appropriate business models for Sandalwood, Whitewood and Canarium

##### Canarium

Data from the literature review were used to develop a financial analysis. Literature data were validated and complemented by interviews with experts in Vanuatu. Cash flow analysis for four scenarios were developed: 1) sale of nut-in-shell, 2) sale of kernel-in-testa, 3) sale of dried kernel using solar dryer, and 4) sale of dried kernel using electric dryer. The financial analysis considered a 30-year project. Sensitivity analyses of discount rate, price of canarium products and labour costs were performed.

##### Sandalwood

A financial model was developed to explore the key factors affecting the financial viability of sandalwood plantations established by smallholders. Data for the financial model were sourced from a comprehensive review of the literature and complemented and validated with information obtained from experts in Vanuatu and Australia. The experts were national and international researchers, business owners, sandalwood growers, government officials and farm managers. The financial model was developed in Microsoft Excel and used a previous model developed by Harrison and Harrison (2016b) as a starting point. The model incorporated the production system proposed by Page et al. (2012c) with 444 sandalwood trees, 556 intermediate host plants and 111 long-term host plants per hectare. A mortality rate of 20% was assumed (Thomson 2006). Silvicultural

practices in the model included weeding up to year seven (Harrison and Harrison 2016a), and pruning up to year four (own assumption). Labour needs were based on Harrison and Harrison (2016a).

### Whitewood

The financial analysis was based on data collected in a literature review and from interviews with experts. Experts included growers, government officials and researchers. Assumed parameters for the model were validated through consultations with additional researchers having experience working with whitewood. A discount rate of 8% was used following Ota et al. (2022a). The breakeven price for whitewood logs was calculated for different scenarios based on the literature. The scenarios were focused on different conditions in relation to planting density and thinning and harvesting ages and intensities. These were modelled for individual and collective marketing of whitewood separately.

## 6. Achievements against activities and outputs/milestones

### Management activities

No.	Activity	Outputs/ milestones	Completion date	Comments
M1	Inception Meeting	M3/Y1 Plan implementation of project	Sep 2017	Inception meeting was held over two days in Port Vila on Mon 10 <sup>th</sup> and Tue 11 <sup>th</sup> September 2017. This was followed by a series of meetings between the project leader and various project staff and collaborators to clarify roles planning initial activities.
M2	Develop project's M&E plan	M6/Y1 M&E plan prepared & finalised	-	The project developed a monitoring and evaluation measure of success for each of the objectives in consultation with DoF (see below).
	<p>The impact measures of success for each component of the project were considered:</p> <ol style="list-style-type: none"> <li>1. Numbers of seed and seedling distribution from improved germplasm sources – for volumes of seed and numbers of seedlings distributed see information included in activity M5 and 2.2.4</li> <li>2. Establishment of Canarium germplasm to support future expansion of plantations. This activity was identified by DoF as being the central output of the project to provide a reliable source of improved planting materials – see information included in activity 1.3.</li> <li>3. TRF processes and markets 100m3 of whitewood, provides financial return to the VFA and whitewood growers. The key measure is that VFA establishes a viable independent business that processes planted whitewood by the end of the project. Information related to activity 4.2</li> <li>4. Improved knowledge transfer associated with peer-mediated extension leads to adoption of peer-mediated extension program by the DoF. Key measure is the number of VDoF independent peer-based grower engagements by the end of the project (Activity 4.1.6).</li> </ol>			
M3	Develop project's Communication strategy	M6/Y1 Communication strategy prepared & finalised (A + PC)	Dec 2017	A strategy for project communication & role descriptions for each of the personnel was drafted and emailed to project staff on Friday 8 <sup>th</sup> September 2017. This formed the basis for discussions with project staff on roles and responsibilities.
M4	Maintenance of existing whitewood and sandalwood germplasm	Ongoing	-	See below
	<p>Significant maintenance operations were conducted during June 2020 Sandalwood GSOs - Tagabe &amp; Onesua and Summit Estate (Efate). At this stage it is evident that Summit Estate have limited capacity to maintain the research plots as per the Material Transfer Agreement. The DoF ACIAR project account has funded the clearing of the site throughout the duration of the project.</p> <p>The germplasm trials in Santo (i) Navota Sandalwood Conservation Plot, (ii) VARTC Sandalwood GSO, (iii) Bombua whitewood Progeny Trial and (iv) IFP seedling seed orchard (SSO) were affected by Cyclone Harold. The most recent information from DoF staff in August 2022 indicate that VARTC sandalwood GSO and Bombua whitewood plots are being used for seed collection. The Navota sandalwood conservation plot has fallen into a state of disrepair due to significant damage and lack of follow up weed control. The status of the whitewood trees at IFP is yet to be determined due to access issues to the site.</p>			
M5	Mid-term Review (MTR) conducted	M12/Y2 Report on Mid- term Review (A + PC)	Jun 2019	Completed 2019  Mid-Term Review meeting was held on 11 <sup>th</sup> -13 <sup>th</sup> June 2019. Mid-Term Review was conducted by Roger Sands and Nora Devoe.  Response to recommendations below

	<p><b>1. Evaluation and monitoring over all objectives should occur to determine the extent of planting and the likelihood of this happening in the future.</b></p> <p>Field observations have found that Canarium is planted opportunistically as individuals or small numbers of trees typically as wildings within the garden system. Seedling distribution data from DoF records is likely to provide an accurate account of the extent of more systematic planting of woodlots for commercial purposes. Canarium seedling distribution data from DoF central (Port Vila) and regional nurseries (Northern, Central, and Southern) between 2012 and 2018 equated to 1200 seedlings per annum.</p> <p>Sandalwood planting between 2000 and 2006 was 14,270 sandalwood trees per annum, resulting in close to 100,000 trees established (Page et al. 2012b). Davila et al. (2021) recorded a further 100,000 seedlings were distributed throughout the country between 2008 and 2012, with half of these being attributed to ACIAR investments. Thomson (2020) reported that the total sandalwood plantation area in 2014, including smallholder and commercial plantings, was 1400 ha in 2014. The most recent survey conducted of Vanuatu primary producers in 2019/20 revealed over 250,000 trees planted in woodlots ranging in age from 1 to 25 years (VPPA data). Establishing seed orchards in accessible locations and allowing all members of the community to collect provides germplasm distribution amongst the community but recording the extent of this distribution can be problematic. The most reliable estimates drawn from production figures from a grafted seed orchard (GSO) in Epi approach 16kg or 48,000 seed per GSO (see activity 2.2.4. The wider distribution of sandalwood seedlings and adoption among smallholders is projected to see a tripling of the annual quota from 80 to 240 tonnes a year as the older woodlots begin to mature (Davila et al. 2021). This has been evidenced in the recent national harvest data recorded by the DoF where 170 tonnes were exported in 2021 (See section on Economic Impacts).</p> <p><b>2. A credible inventory of whitewood resources should be undertaken.</b></p> <p>A representative set of plantation plots was established across the estate to provide reliable data about that wood supply. Over 40 plots, each of which was 0.05 Ha were put in place and measured. The data was extrapolated across the estate and the current available merchantable wood volume is around 30,400m<sup>3</sup>. A total of 65% of the of the estate owned by Melcoffee and not available to the TRF. The current merchantable wood volume available for TRF processing is approximately 10 675m<sup>3</sup>. This equates to an annual production resource of 100-500m<sup>3</sup>.</p> <p><b>3. Whitewood research should place high priority in evaluating whether or not there is a viable value chain taking whitewood from the forest through to market.</b></p> <p>This research has already been conducted where the majority of whitewood consumers in commercial domestic markets were builders, and timber yards providing the main connection with suppliers The study found that consumers preferred whitewood over imported soft wood, however the supply of whitewood timber was limited in meeting domestic demand (Viranamangga 2013). The key research question related to the utilisation of young knotty whitewood associated with commercial thinning. The research will be conducted once the TRF has been reconstructed and SCU project staff have had a chance to commission the equipment to operational standard in August 2022.</p> <p><b>4. Draft reports should be finalised and published if appropriate.</b></p> <p>Reports published by the project have been included in section 12.2 List of Publications.</p> <p><b>5. Financial analyses and business models need to be based on objective and verifiable data.</b></p> <p>Additional data was collected from a range of stakeholders for each of the three products. Every effort was made to draw upon the expertise of primary producers, traders, government representatives and researchers during the project. This was made possible through the MTG events, the Sandalwood Regional Forum held in November 2019 and direct contact with key informants. For Canarium, measurements of smallholder processing efficiency (harvesting, depulping and cracking) were made and confirmed through active re-testing by researchers with experience in processing gained during the Canarium morphology survey.</p> <p><b>6 There should be a plan on how the Department of Forests utilises the Timber Research Facility after this ACIAR project has been finalised.</b></p> <p>This recommendation was included as a provision in the Memorandum of Agreement (MOA) to ensure transparent management of the accounts, data collection, storage and reporting. Based on the viability of the operation, the VFA (Vanuatu Foresters Association) will be required to secure a license recognised by the Republic of Vanuatu to operate on a commercial business. Much of the information required to furnish the plan will be generated during the implementation of timber processing and marketing operations.</p>			
M6	End of Project Review	M10/Y4 Report on EoPR (A + PC)	-	End of Project Review was led by Dr Richard Markham and Dr. Cherise Addinsall. The review meeting was held on 2 <sup>nd</sup> and 3 <sup>rd</sup> May 2022. Project participants from DoF, SCU and USC presented the process, outputs and outcomes from each of the four project objectives. Due to travel restrictions in place to enter Vanuatu from Australia, the meeting was held remotely through online meeting platform. Site inspections and stakeholder interviews were held at a later date in May/June 2022 when Dr Addinsall was permitted to travel to Vanuatu. The EoPR report was not available prior to the finalization of this report.

### **Objective 1: Enhance availability of improved quality *Canarium* seed through evaluation and capture of wild resources**

No.	Activity	Outputs/ milestones	Completion Date	Comments
<b>1.1</b>	<b>Characterise existing <i>Canarium</i> genetic resources by random and targeted sampling</b>			
1.1.1	Review local knowledge about the biology of the species, its variability, exploitation and processing.	Report of local knowledge about <i>Canarium</i> distribution and variability	Oct 2018	Joseph Tungon completed an internal report that covered information about <i>Canarium</i> in the literature as well as information about the local variation and variability. The contents of this report provided Vanuatu smallholder-specific information for the production of the <i>Canarium</i> producers manual associated with task 1.4.2
1.1.2	Determine traits of interest for evaluation of natural variation & develop survey/selection strategy.	Record of survey strategy.	Oct 2017	Traits for measurement were determined through collaborative discussion among project partners during and after the project Inception Workshop. Those that contributed to this process included Joseph Tungon, Hanington Tate, Noel Kalo, Helen Wallace, Bruce Randal, Paul Macdonell, Tony Page, Alain Jacobe and Voutausi Mackenzie. The primary traits for consideration of domestication were related to kernel dimension and mass. It was clear that larger kernels were preferred by processors and consumers largely owing to processing efficiencies associated and consumer appeal of larger kernels.
1.1.3	Characterise tree-to-tree variation in at least 150 natural and planted trees of <i>Canarium</i> from 5 islands.	Identification of candidate selections for selection	Dec 2018	Fruit/kernel data and seed from 256 trees over 10 sites from 8 islands were collected in 2017 & 2018. The islands included Pentecost, Ambrym, Santo, Epi, Paama, Tongoa, Malekula and Malo. A total of 80 trees were collected in 2017 (seed recollected in 2018) and 170 trees in 2018. The seeds were brought back to Port Vila and DoF nurseryman Paul Stanley sowed in ground-beds within the Tagabe nursery. All seedlings succumbed to a wilt causing disease in both years, most likely promoted through an extended wet period through the cooler months of June to August.
1.1.4	Report on morphological variation in <i>Canarium</i> in Vanuatu.	Research manuscript on morphological variation in <i>Canarium</i> in Vanuatu	-	Manuscript for publication in a peer reviewed journal has been prepared and nearing submission (Grant et al. 2022a). The manuscript includes multi-year measurements and yield estimates from a <i>Canarium</i> agroforestry plot in Malekula.
1.1.5	Make selections based on key selection criteria	Seedlings produced for planting in provenance progeny trial	Dec 2019	Two selection paths were adopted based on high levels of kernel mass for: 1) single kernels only, and 2) combined kernels (both single and double). Other important traits such as ease of cracking were subjective and difficult to evenly apply across all trees. Large kernel trees were universally accepted as being the most desirable trait by all interested parties.  The largest 75 trees were selected from each pathway and resulted in a combined selection list of 119 trees.  Approx. 75 fruits from each of the 81 selections were collected for sowing in 2019. The remaining 38 trees had no fruit available. Seed were supplied to DoF and VARTC plant nurseries in Santo for germination and production of seedlings.
<b>1.2</b>	<b>Adapt and apply existing methods for clonal propagation of selected individuals</b>			

1.2.1	Key project staff to visit PNG to examine existing techniques for clonal propagation of Canarium	Milestone not achieved due to travel restrictions associated with COVID-19	-	The project had planned to conduct this visit during mid-2020 during the Canarium fruiting season. However due to travel restrictions related to CoVid-19 this has not been possible.
1.2.2	Develop facilities for clonal propagation of mature canarium in Vanuatu.	Facilities ready for cloning & cloning protocol established	Dec 2017	A shade house was constructed at the nursery in Tagabe to conduct grafting and budding experiments for both sandalwood and Canarium.
1.2.3	Conduct adaptive propagation experiments with canarium	Report on propagation of mature Canarium in the Pacific	Jun 2020	Budding and grafting experiments were conducted in late 2018 and mid-2019 using mature material grafted onto seedling rootstock. Despite multiple attempts across four small trials, success was only achieved with seedlings grafted 'back onto themselves'. No mature scions formed a successful union with seedling rootstocks. The main issue with the technique is the mismatch between stem diameters of mature trees and seedling rootstocks. This makes correct alignment of the cambium layers challenging for both methods. For these methods to be successful, seedlings would likely need to be grown in large pots, so the stems are of sufficient diameter.
<b>1.3</b>	<b>Capture selected trees by a combination of clonal and seed-based methods to establish a population for tree selection</b>			
1.3.1	Collect and germinate Canarium seedlings for use as rootstock	Seed- rather than clonal-based domestication was pursued in this project	Dec 2019	On the basis of challenges with clonal propagation of mature Canarium, the project pursued the seed-based route for collecting and propagating selected trees in the wild (see task 1.3.3).
1.3.2	Establish germplasm use agreements with industry partners	An informal agreement was established between the DoF and VARTC for the establishment and maintenance of the Canarium provenance progeny plot established at VARTC	2020	A use agreement was drafted and sent to VARTC in August 2019. Further meetings and discussion were held between DoF and VARTC senior staff. On the basis that both organisations are part of the Ministry of Agriculture (MALFFB) it was considered that co-operation could proceed without the need for a formal agreement. Such arrangements have been successful with the sandalwood GSO in the past. A meeting was held at VARTC in Nov 2019 and again in June 2022. VARTC confirmed their support to host the trial. The project will fund the establishment with VARTC cooperation and maintenance beyond the life of the project will be funded by both DoF project funds and VARTC in-kind contributions.
1.3.3	Propagate by clonal and seed-based methods the selections based on information from activity 1.1	Seedlings were produced in two plant nurseries in Santo (DoF and VARTC)	Nov 2019	Seed collections were made in Oct-Nov 2019 from selected trees based on seed kernel mass data collected from the survey (see activity 1.1.3). Seeds were sown at DoF and VARTC nurseries in Santo. While seedling losses were incurred following water supply issues associated with Cyclone Harold, there were sufficient seedlings across 37 families to use as the basis for a provenance progeny trial (see activity 1.3.5).
1.3.4	Capture selections propagated in task above.	Seedlings were produced in two plant nurseries in Santo (DoF and VARTC)	Jan 2022	Fungal wilt plagued the two seed collections conducted in 2017 and 2018. These outbreaks were promoted during the cooler and wetter months in Efate (May to Aug). These issues have been recorded and documented in the producers manual. Seed collected in 2019 was in nurseries in the warmer region of Santo. The split between the DoF and VARTC nurseries was undertaken to reduce risk of fungal wilt.

1.3.5	Establish clonal/seed-based germplasm repository	A site at VARTC in Santo was prepared and planted as a provenance progeny trial	Apr 2022	VARTC provided a suitable site in Santo to plant the Canarium germplasm trial. A trial design was based on the seedlings available in the VARTC nursery during May 2022. The trial was planted in June 2022 by VDoF and VARTC staff. The trial represented 37 families planted as 3-tree line plots and each line plot replicated up to three times.
<b>1.4</b>	<b>Evaluate existing Canarium crop management methods &amp; develop smallholder-appropriate systems</b>			
1.4.1	Conduct review of cultivation practices developed in Vanuatu and other Pacific Islands	Review reports were consolidated as a Canarium production manual in 1.4.2	Dec 2018	The review documents authored by William McNeice, Elektra Grant & Joseph Tungon were produced and have been combined together with a range of research-informed technical notes to form the basis of the Canarium production manual. (See activity 1.4.2)
1.4.2	Document current cultivation practices	Production manual for Canarium production in the Pacific	Dec 2021	The manual has been finalised and covers information from seed collection, through production, processing and marketing. This document is well suited for publication in ACIARs monograph series. It caters for researchers, extension practitioners, producers and processors across Melanesia.
1.4.3	Support for Canarium industry development objectives.	M6/Y3 Workshop held.  M12/Y3 Report on achievements under Plan.	-	A financial analysis for Canarium production has revealed the casual, inconsistent supply of canarium nuts in Vanuatu can be seen as a cause and a result of the opportunistic labour it relies on. With a very low labour opportunity it remains a challenge for industry expansion. The non-financial gains might make up for the challenges of selling fresh kernels as it is practiced currently. For instance, cracking the nuts might be a social activity, and women might benefit from extra cash that they would not have access to otherwise. A review of current industry structure and exploration of potential avenues for developing inclusive value chain has been conducted through interviews with key industry informants government representatives and researchers and provided for stakeholder feedback and further refinement. The document that covers all three focal species has been submitted for scientific publication.

**Objective 2: Improve the value of planted sandalwood by widening the deployment of improved genetic resources (~25%).**

No.	Activity	Outputs/ milestones	Completion Date	Comments
<b>2.1</b>	<b>Develop participatory domestication strategy.</b>			
2.1.1	Develop participatory domestication strategy for sandalwood	Domestication strategy published.  Grading system published  Production manual published	Dec 2020  Jan 2022  June 2022	The domestication strategy was finalised and presented at the Sandalwood Regional Forum and included in the proceedings. The strategy was published in the scientific journal Australian Forestry (Page et al. 2020a).  A grading system was published as a paper on the Sandalwood Regional Forum proceedings (Page and Doran 2021)  To support the ongoing production of Vanuatu sandalwood, the project made significant contribution to the publication of a production manual as an ACIAR monograph

2.1.2	Establish germplasm use agreements with industry partners	Signed agreements  Document on domestication resources	Jun 2020  Jun 2022	MTAs were finalised between DoF and the recipients of the germplasm (see activity 2.2.3). These agreements entailed the transfer of improved germplasm (grafted clones) from DoF to each of the stakeholders. The main provisions within the agreements included (1) rights to propagation for internal research and production purpose such as plantations on lands owned by or managed (e.g., smallholder recipients in existing or new out-grower networks) by the recipient and (2) restrictions on international export of the germplasm either directly or through third parties and conditions of distributing to smallholders. There were additional provisions on the recipient to provide the VDoF with data on distribution of clones and improved seed and access to trials and data on their performance. A document that outlines these and all other germplasm sources that contribute to the domestication strategy has been produced (Page et al. 2022b).
<b>2.2</b>	<b>Establish next generation breeding resources for sandalwood.</b>			
2.2.1	Evaluate planted sandalwood resources to identify candidate selections for inclusion into breeding trials (2.2.3)	Report on productivity of planted sandalwood in Vanuatu	-	Methods for selecting plus trees in plantations were described in detail in the sandalwood domestication strategy (Activity 2.1). Activities directed at evaluating planted resources of sandalwood for candidate selections took place at Summit Estate with key DoF research staff in conjunction with the heartwood SRA study (FST/2016/054) (Page 2018). This culminated with the identification and marking of eight trees with precocious heartwood development (Page 2019). Arrangements were made with Santal Valley to undertake similar assessments of their planted resource, but with changes in research staffing during the project there were no opportunities to undertake further resource assessments and selections.
2.2.2	Propagate existing improved germplasm and candidate selections by seed and/or clonal methods.	Small batches of improved germplasm were produced throughout the project.	2018-2020	Tagabe clonal archive was the source of scion material used for their propagation as grafted clones. The grafted stock were distributed to recipients for establishment of satellite grafted seed orchards (see task 2.2.3). Experienced forestry researcher Joseph Tungon was contracted to the project as a consultant to build capacity among then research staff Toufau Kalsakau and Paul Stanley to implement critical project activities including (1) Site management practices for sandalwood GSOs & progeny trials to produce high quality seed and scions (2) management of sandalwood seedling rootstocks in the nursery at Tagabe and (3) correct practice of sandalwood grafting to duplicate the Tagabe clones and capture selected trees identified at Summit Estate.  Two grafting training courses were conducted by David Spencer, Joseph Tungon and Michael Tabi, for staff working with commercial sandalwood growers. This culminated in the preparation of a detailed Technical Note and Presentation on grafting of sandalwood (Spencer et al. 2018a, b).
2.2.3	Establish seed orchards, progeny trials and/or genetic gain trials with industry partners.	A total of four grafted seed orchards and one sandalwood progeny trial established with industry	Nov 2018 to May 2022	The Grafted Seed Orchards established by the project include: <ol style="list-style-type: none"><li>1. Summit Estate (Efate) – Mar 2019</li><li>2. Andrew lawak (Tanna) – Dec 2019</li><li>3. Edmond Julun (Malekula) – Apr 2020</li><li>4. Santal Valley (Efate) – May 2020</li></ol> A progeny trial was established at Summit Estate in July 2018.



2.2.4	Quantify seed distribution from improved germplasm resources	M6/Y4 Report on effectiveness of participatory domestication of sandalwood in Vanuatu.	-	A summary document was produced that provides an account of the improved sandalwood genetic resources established with ACIAR supports. These represent a source of improved seed for further research and for growers to establish woodlots in the respective islands. The quantification of seed has relied on co-operation of recipients of the germplasm. The purpose for deploying GSOs with local collaborators was to ensure availability of the best germplasm for establishing woodlots in areas where such opportunity didn't previously exist. While such a model places germplasm at the heart of community, it does present challenges in remotely quantifying distribution and recording the impact of this strategy. Data collected by the hosts of the Epi GSO in 2018 revealed that each grafted tree produces approximately 440 grams of seed per year. This equates to an annual production rate of about 16kg or ~62,000 seed (~3,900 seeds per kg (Thomson 2006)) for each of the GSOs.
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**Objective 3: Enhance knowledge and capacity within whitewood value chain stakeholders, of growing, processing and marketing of high and lower value wood products (~25%).**

No.	Activity	Outputs/ milestones	Completion Date	Comments
<b>3.1</b>	<b>Conduct inventory of current plantation resource on Santo</b>			
3.1.1	Gather currently available data on resource character on Santo.	Summary of currently held inventory data (quantity and quality) and known location of plantations.	July 2018	The extent of planted stands was drawn from a survey conducted in 2007 and a review of existing seedling distribution data that gives a relative indication of planting intentions. This data contains gaps where seedling distribution was not recorded or where it has since been lost.
3.1.2	Use local media to call for landholders to identify plantation resources.	Deliver updated assessment of plantation resource locations. Prepare a plan of work for field survey.	July 2018	Much of the information on maturing woodlots was sourced through a previous woodlot survey and whitewood seedling distribution data (see 3.1.1 above). This information gave sufficient insight into the extent of planting and the basis for developing a woodlot sampling strategy.
3.1.3	Enlist technical officers of DoF to be trained and to conduct surveys.	M12/Y1 Survey methods designed and presented as field proformas. Staff identified and trained.	Jan 2019	A representative set of plantation plots was established across the estate to provide reliable data about wood supply. Over 40 plots, each of which was 0.05 Ha were put in place and measured.
3.1.4	Report	Report results of inventory, including potential wood flows by type and quantity over 10 years.	Jul 2019	Report of inventory completed and an estimate of potential annual production prepared (Grant and Palmer 2019). At the current time, a small volume of saw logs is available annually (~100 to 500m <sup>3</sup> ) implying small scale production only. This volume will likely be consumed domestically but will desirably demonstrate viability and motivate an upscale in planting.
<b>3.2</b>	<b>Continue to build the market for structural wood by developing methods of construction and educating builders.</b>			

3.2.1	Develop management plan for the Timber Research Facility	M6/Y1 Agreed management plan for TRF M10/Y2 Interim report on processing and sales from TRF M6/Y4 Agreed plan for future management of TRF M9/Y4 Report on achievements of TRF	2021-2022	<p>The Vanuatu Foresters Association (VFA) has been the manager of the TRF. The VFA have been working with DoF and the Vanuatu Agriculture College (VAC) to organise the reconstruction of the TRF from mid-2021 to mid-2022 (Kaku 2022).</p> <p>The treatment extension vessel and other items such as fans for kiln drier, sensing equipment for kiln and mechanical properties testing were shipped from SCU to Vanuatu in July 2022. Graeme Palmer and Kevin Glencross have to commission the TRF in collaboration with VDoF staff on behalf of the VFA. It is envisaged that this will put the VDoF and VFA on a positive footing to begin processing plantation grown whitewood and demonstrate the viability of the business model.</p>
3.2.2	Develop grading systems and structural design code in conjunction with item 3.2.2.	M12/Y1 General structural design documentation prepared	-	<p>A visual whitewood timber grading system has been completed with finished graphics (Palmer 2020b). This document was provided to DoF in Nov 2020. Feedback from DoF and wood users in respect of the specifications of each grade is required to ratify the validity of the grading system. Informal feedback from Melcoffee sawmill manager, Steve Croucher, has indicated the draft is satisfactory, however note is made that some experience using the standard is needed to assess its application in actual operations.</p>
3.2.3	Engage engineers/designers to provide building designs that meet cultural conventions and structural demands of weather.	M9/Y2 Example building design options	-	<p>An independent engineer has developed a building design for utilising sawn whitewood sourced from planted woodlots. The design is based on the Australia Standards for a stick frame construction with more distributed tie-downs coupled with bracing. The code cannot be completed in the absence of further mechanical testing of timbers graded suitable for the application. These tests, while planned, have been unable to be completed during the pandemic when travel from Australia was prevented. The future development will depend on feedback from stakeholders to be surveyed during a final workshop in 2022.</p>
3.2.4	Planning for new demonstration structure(s)	Y2/M9 Evaluation of effectiveness of existing demonstration structure and identification of options for new demonstration  Y2/M12 Agreement on nature of additional demonstration structure (s)	Apr 2020	<p>The demonstration building at DoF in Santo was completed to the point of fitting roof sheets during November 2019. Subsequent cyclone proved the structure to be sound while adjacent buildings were heavily damaged. The design based on Australian building standards for cyclonic wind loads has proven effective.</p> <p>According to DoF reports the building is currently being used as an office, due to the destruction of the DoF offices.</p>
3.2.5	Produce materials for construction	M6/Y3 Required timber available, identified and set aside awaiting use.	-	<p>Production of whitewood timber will commence once the TRF can begin processing again. Scheduled start up of processing in the second half of 2022</p>

3.2.6	Construct display structure (s).	M12/Y3 Display home available in Luganville.  Report and promotional materials prepared.  M10/Y4 Agreement on future use or disposal of demonstration structure(s)	-	Due to the need to reconstruct the TRF following Cyclone Harold it was not possible to produce the sawn. Timber to support the construction of a display structure. This project activity was not achieved. This
<b>3.3</b>	<b>Evaluate the effectiveness of smallholder-appropriate technologies to improve the durability of whitewood for local-subsistence construction.</b>			
3.3.1	Identify by literature review options for low cost chemical treatments.	M6/Y1 literature review – treatment options defined	May 2019	A summary of results of this review has been prepared. CaCO <sub>3</sub> (coral) and seawater are the main options appears to offer some potential to providing low cost protection. These methods are however ineffective in addressing the issue of blue stain.
3.3.2	Acquire suitable timber samples for test purposes and prepare these with selected treatments identified in 3.3.1	Required timber available identified and set aside awaiting use.	Jan 2018	Based on the results of literature review and work previously done installing above ground durability tests at TRF, the new installations will only include samples treated using CaCO <sub>3</sub> and will be installed with samples currently in test.
3.3.3	Establish trials at appropriate scales to test the efficacy of treatment.	Test structures established	-	Test samples treated with coral diluted in acid solution were prepared and placed into test with other previously established test specimens, during November 2019. On site technician Sammy Kaku has informed all specimens have been recovered and stored post cyclone Harold.
3.3.4	Analysis of graveyard preservation trials established under FST/2012/042	Report of results from graveyard preservation trials	-	Delayed until restart of travel.
3.3.5	Preparation of report and extension materials	Prepare and submit report and extension materials of findings.	-	N/A
3.3.6	Review local and other available technology in both forestry and agricultural context that contribute to low cost drying plant design.	Document the results of this survey in terms of application in wood drying to feed into 3.5.2	Jun 2020	Completed 2020  Reviewed glass house design and local coconut driers. Subjective assessment suggests Santo has too many cloudy days for effective solar drying. Hot water systems are too complex and therefore expensive. Plenty of wood fuel indicates it as being the potential best option. A design drafted based on an insulated wood structure and fireplace, with airflow being derived from 24 volt solar-driven fans.
3.3.7	Prepare wood dryer design options	Produce dryer design options and estimates of capital and operating costs. Produce an informal technical report of findings.	Jun 2020	Completed 2020  Dryer design completed (Palmer 2020a) but work for construction delayed due to national inventory and cyclone Harold. DOF Tech Sammy Kaku is negotiating construction cost along with rebuild of TRF.

3.3.8	Construct a dryer and test the productivity and quality of drying.	Completed wood dryer and associated performance information	-	This activity will commence with lifting of travel restrictions to Vanuatu. Ancillary equipment will be shipped in advance together with treatment cylinder extension.
3.3.9	Trialling of wood dryer and dissemination of knowledge	<p>Technical specifications and financial report.</p> <p>Field Workshop to demonstrate application of low-cost wood dryer</p> <p>Extension document for smallholders on locally appropriate wood drying technologies</p> <p>Report on effectiveness of locally appropriate wood dryer</p>	-	N/A

**Objective 4: Increase adoption of existing technologies for planted forests through improved knowledge development and transfer among stakeholders**

No.	Activity	Outputs/ milestones	Completion Date	Comments
<b>4.1</b>	<b>Improve accessibility of existing knowledge on plantation forestry to increase rates of adoption.</b>			
4.1.1	Identify relevant forestry extension materials and local delivery mechanisms	Evaluation report on current state and performance of forestry extension in Vanuatu.	Jan 2018	A review report of agricultural extension services and their relevance to agroforestry and farm forestry was produced (Reid et al. 2018). This report also formed the necessary background for informing the need for alternative perspectives on forestry extension and how to implement the Master TreeGrower Program in Vanuatu.

4.1.2	Empowerment of women	Contribution to the publication on Agroecology and Sustainable Livelihood as a Framework to Empower Rural Ni Vanuatu Women	May 2019	<p>From project commencement, key project staff identified that resource constraints necessitated a focused approach to 'empowerment' activities. It was therefore agreed with the ACIAR program manager that engagement with women be linked with their participation in the MTG and other extension related activities of the project. The project then assessed the relative success of these engagements in terms of technical adoption and knowledge transfer among social networks.</p> <p>The VDoF identified female extension practitioners Anne-Marie Sarisets and Judy Kalotap to be the main points of contact for the roll-out of the MTG workshops. These officers were also proactive in the implementation of a women-only MTG event in Malo Island in collaboration with Votausi McKenzie who is a female entrepreneur processing indigenous nuts. The effect of this MTG on its female participants was assessed and documented (Addinsall 2019). DoF staff had planned to go back to Malo in 2020 to conduct some awareness and determine the effect of the MTG training on knowledge transfer and adoption of tree planting. Unfortunately, Malo Island was affected severely by Cyclone Harold. Communication with participants following the event revealed that their families had more pressing livelihood issues to attend to and were unable to consider tree planting within such a context. The project was guided by VDoF staff on how to go about working with the women participants in the Malo MTG.</p>
4.1.3	Build understanding of MTG with DoF extension technicians	<p>DoF extension officers trained in the delivery of MTG.</p> <p>Resources including MTG structure, presentations, videos, images and documents provided for DoF extension staff use.</p>	Nov 2019	<p>Training in MTG delivery was provided for the following staff members:</p> <p>1<sup>st</sup> Efate – Anne-Marie Sarisets, Michael Tabi, James Samuel.</p> <p>2<sup>nd</sup> Malo – Anne-Marie Sarisets, Joseph Tungon &amp; Mesek Sethy.</p> <p>3<sup>rd</sup> Santo – Anne-Marie Sarisets, Mesek Sethy &amp; Frank Joely.</p> <p>4<sup>th</sup> Efate – Judy Kalotap &amp; Toufau Kalsakau.</p> <p>Resources to support independent delivery of an MTG peer-to-peer style extension were provided to VDoF extension. These included PowerPoint Presentations, Promotional (14) and instructional videos (17 and 74 videos respectively) all delivered in local language Bislama. DoF forest inventory videos DoF Forest Inventory Videos (17 videos). PDF documents that cover key topics including (1) Tree Forest &amp; Measurement, (2) Principles &amp; Practice of Pruning, (3) Practical note on Pruning &amp; Thinning and (4) Growing high quality sawlogs. A total of 100 USB flash drives were provided for the distribution of these resources to participants. Project funds were made available for VDoF to secure any further resources and equipment to deliver future MTG workshops and associated follow-up events. DoF extension staff had developed a plan for continuing this work (see activity 4.1.6).</p>

4.1.4	Trial the MTG for application in three focal communities or grower groups.	Four MTG workshops delivered	Nov 2019	<p>1<sup>st</sup> Event with Shefa province in mid 2018</p> <p>2<sup>nd</sup> Event with Canarium grower group (female extension) in Malo with suppliers for Lapita Café in Sep 2018</p> <p>3<sup>rd</sup> Event was conducted in April 2019 with a whitewood grower group.</p> <p>4<sup>th</sup> Event conducted in Nov 2019 with sandalwood growers from around the country. This event coincided with Sandalwood Regional Forum (Reid 2019) with participants attending a study tour.</p>
4.1.5	Evaluate and adapt the MTG for application by extension agents in Vanuatu.	Evaluation report on effectiveness of MTG and mechanisms for further refining for Vanuatu.	Nov 2020	Review reports for the two Santo (Addinsall 2018, 2019) and one Tagabe (Page 2020) MTG training events have been provided to DoF. MTG Training materials were translated from English to Bislama by DoF staff address the responses from the MTG participants. A concise planning and strategy document based on the recommendations outlined in the three review reports was provided to DoF (Page et al. 2020b) for feedback and further alignment with DoF perspectives.
4.1.6	Delivery of refined MTG by DoF extension agents.	M9/Y4 Report on evaluation of dispersion and adoption of agroforestry following MTG training	2021-2022	The DoF consider the MTG an important extension tool for connecting tree farmers and building local capacity to establish, manage and market their woodlots. DoF has sought to accommodate the MTG in their business plan. The extension section has now allocated the MTG in their yearly operational plans for Shefa Province. The MTG field day for Efate and its offshore island Tongoa were scheduled for 2021. The MTG in in Tongoa was to explore how land constrained farmers can improve the utilisation of their land through incorporation of trees in their agricultural landscape. This event had been delayed through restrictions in travel, and was rescheduled for Sep 2022.
4.1.7	Improve accessibility of existing knowledge in plantation forestry through radio, print and social media.	A forestry-centred radio program that delivers essential information for the forest industry in Vanuatu.	-	<p>During the life of the project the DoF Facebook following has increased as follows:</p> <ol style="list-style-type: none"> <li>1. ~500 in mid-2017</li> <li>2. ~1200 in mid-2018</li> <li>3. &gt;2500 in mid-2019.</li> <li>4. ~3700 in mid-2020</li> <li>5. ~4200 in mid 2021</li> </ol>
4.1.8	Evaluate the effectiveness of stakeholder engagement with 4.1.5 & 4.1.6.	Research publication on smallholder extension in Vanuatu	2019	The effect of the MTG on its participants was assessed, documented (Addinsall 2018, 2019; Page et al. 2020b) and ultimately contributed to a research publication (Addinsall et al. 2019). This research evaluated the effectiveness of the training based on participant engagement and knowledge acquisition through feedback (interviews). Medium term assessments of the training's impact on knowledge transfer among peers and ultimately adoption of locally-relevant tree planting and application of sound management was not possible during this project. This was primarily due to restrictions in both international and domestic travel, combined with the adverse effects on participating communities from Cyclone Harold. This limited the capacity of project staff to access MTG participants for follow up assessments and interviews.
4.2	Build industry capacity to understand and manage key aspects of the timber industry value chain.			
4.2.1	Create & implement the Whitewood Market Development Group.	Market Development Group established	Dec 2018	With the Vanuatu Foresters Association assuming control of the Timber Research Facility (TRF) in Santo there was little partner support to develop the Whitewood Market Development Group (WMDG).

4.2.2	Present the purpose of the Market Development Group and develop a business plan	M12/Y1 Terms of Reference for MDG developed. Report on private sector and market development for whitewood  M12/Y2 Revised Business Plan and options for long term management	-	Developing a business plan for the operation of the TRF will depend upon reliable production data generated from the facility itself. This data is likely to become available following the commissioning of the TRF in Sep 2022. During the delivery of the project SCU liaised with the Department of Industry (DoI) to undertake a domestic whitewood market survey & analysis in Port Vila. Based earlier market analysis conducted (Viranamangga 2013), it is reasonable to consider that there will be no issues in marketing such volumes in the domestic markets in Port Vila and Luganville. We now understand the volumes of whitewood expected to flow from planted woodlots is between 100 to 500m3 per annum.
4.2.3	Assess the function and effectiveness of the Market Development Group.	M10/Y2 & M120Y4 Reports on the achievements and effectiveness of Market Development Group	-	The processing of whitewood timber by the Vanuatu Foresters Association (VFA) in the Timber Research Facility (TRF) offers the opportunity to record productivity and sales data to develop a business plan for the sustainable operation of the facility while providing suitable financial returns to all those operating within the value chain. The TRF was reinstated in August 2022 and it is expected that meaning data will flow from the facility post-project.
4.2.4	Reconstruct the TRF Facility following Cyclone Harold in April 2020.	Second half of 2020	Jan 2022	The reconstruction of the TRF commenced in June 2021 and was completed in January 2022. The structure was constructed to withstand future cyclones. The TRF comprises a sawmill purchased in 2012 and a second Woodmizer LT 36 is proposed for purchase by VFA. The pressure treatment plant originally installed is being extended to accommodate lengths up to 4.8m. Equipment enabling the construction of a wood-fired drying kiln has been supplied and construction will occur during second half of 2022. Other original equipment including rip and crosscut saws, saw sharpening tools and general maintenance tools has been supplemented with replacement power tools and yard maintenance tools. The TRF was connected to the electricity network and can be backed up by two generators originally intended for providing power to the site. This will increase the reliability and reduce the cost of power to service key infrastructure.
4.3	Develop locally appropriate business models for Sandalwood, Whitewood and Canarium			
4.3.1	Undertake Financial analyses for Sandalwood, Whitewood and Canarium.	Financial models for sandalwood whitewood and Canarium with provision for assessing mixed species plantings		The canarium model was refined together with the associated report on the financial viability of smallholder canarium production from orchard plantings (Ota et al. 2021).  The sandalwood financial model and associated research manuscript was provided to DoF for their information and feedback. The manuscript was published as a DoF/USC co-authored paper in Small-scale Forestry in mid-2022 (Ota et al. 2022b)  The whitewood model was developed based on research informed assumptions, with adjustments made based on collective action for harvesting operations (Ota et al. 2022a).
4.3.2	Develop a modified financial model to simplify use and improve adoption by project partners and stakeholders	Modified FMs with user-friendly interface provided to DoF for training and extension.		The sandalwood model has been developed as an online user-friendly interface, which allows potential investors to modify some key assumptions < <a href="https://sites.google.com/site/agroforestrytreeproducts/">https://sites.google.com/site/agroforestrytreeproducts/</a> >. It is yet to go live but will be made available for DoF staff to engage with potential growers and investors. The other financial models will be made available through the same platform. This will make the model available over the long-term.

4.3.3	Develop broader business models for the three species.	Business models provided to DoF through a training workshop	-	A report that details the contemporary structure of the value chain for each of the three species (canarium, sandalwood and whitewood) and proposal for potential adaptation of each towards a more inclusive value chain has been written (Carias et al. 2022a). The report was based on a thorough review of the literature and interviews with key industry stakeholders. The report was provided to DoF in Jun 2021 for their critical feedback and presented at the Final project workshop. It has been submitted for publication in a peer-reviewed journal.
4.3.4	Update and further develop domestication strategies for Canarium and whitewood	Domestication strategies completed	-	Domestication strategy documents for both canarium (Macdonell et al. 2022) and whitewood (Doran et al. 2021a) were completed and have been provided to the DoF for their use and implementation. These were based on germplasm developed within this and previous ACIAR and other donor-funded projects. The domestication strategies were developed with the likely resource constraints encountered with projects funded under recurrent government allocations. The domestication strategies also identify key research considerations for the more efficient breeding of the species to achieve sustainable genetic gains.



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## 7. Key results and discussion

### **Objective 1: Enhance availability of improved quality *Canarium* seed through evaluation and capture of wild resources**

#### **1.1 Characterise existing *Canarium* genetic resources by random and targeted sampling**

The nuts of *C. indicum* were characterised across eight islands in Vanuatu sampled across three years. Significant tree-to-tree variation in fruit, nut-in-shell (NIS) and kernel dimensions and mass as well as kernel recovery (K:N) was found. Little of this variation could be attributed to the location from which the tree was sampled suggesting possibly no effective isolation between populations, i.e. anthropogenetic seed movement between islands took place. The study also demonstrated significant linear correlation among important fruit, nut and kernel traits, particularly between kernel mass with each of fruit ( $R^2$  0.57) and nut mass ( $R^2$  0.56). This means that trees may be screened based on fruit and nut mass before making final selections based on kernel mass. Trees were found to produce primarily single-kernel nuts with the occasional double- and rarely triple- kernel nuts. Kernels derived from single-kernel nuts were found to have significantly greater mean kernel mass and kernel thickness, which are important commercial characters. Trees were sampled over a period of three fruiting seasons and it was found that kernel mass and kernel number varied between years. Those trees that produced larger kernels in the first year of sampling tended to maintain their ranking among the trees in subsequent years. The results from this study have important implications for further domestication of the species to produce forms that are desirable for planting in commercial agroforestry systems (Grant et al. 2022a).

#### **1.2 Adapt and apply existing methods for clonal propagation of selected individuals**

Marcotting has proven effective in the capture of genotypes of phenotypically superior *C. indicum* individuals but is impractical for capturing large numbers of mature selections in remote field locations. *Canarium* has been found to be difficult to propagate by cuttings (Gunn et al. 2004), so grafting and budding were tried as alternative vegetative propagation methods across four trials undertaken by the project. This work demonstrated that it is possible to graft juvenile stems when there is no possibility of genetic incompatibility (intra-genotype grafting)(trial 1). Unfortunately, similar success was not replicated when reproductively mature scions were used to graft onto seedling rootstock. In three separate experiments (trials 2, 3 & 4) the mature stems failed to form a successful union with a seedling rootstock. It is possible that genetic incompatibility might be operating with canarium to limit inter-genotype grafting. It is equally likely, however, that the mismatch in stem diameter between the rootstock (narrow) and mature scion (broad), together with the unevenness of the cambial layers may be contributing to graft failure. The two methods (patch & chip) of budding tried were also unsuccessful. The results from these trials indicate that canarium is challenging to propagate vegetatively through grafting and budding and these methods are not yet suitable for capturing selected trees from the wild. Because this work is not published elsewhere we provide details, including photographic representation, within this report. Further research is warranted on *C. indicum* to try and develop robust techniques to enable superior trees to be multiplied via grafting and/or budding.

##### Grafting trial 1

This trial involved grafting seedlings back 'onto themselves' using the cleft and side grafts. Seedlings were grafted 'onto themselves' to avoid any genetic incompatibility. These seedlings were in various stages of recovery from the leaf fungal rot and were used as

they were the only candidates available in the nursery at the time. This technique resulted in some success with 2 successful grafts from 12 grafted plants (10%) on the 1/11/18 and 6 successful grafts from 14 plants grafted (42%) on the 8/11/18. Grafts were assessed on 28/11/18). Figure 2 shows a newly grafted scion with vegetative growth evident at one month after grafting.



**Figure 2: Grafting of seedlings 'onto itself' in Nov 2018 (left) and successful union formed four weeks later in Dec 2018 (right).**

### Grafting trial 2

Mature scion was collected from a tree nearby to the nursery and there was no successful grafts from the 6 attempted on the 1/11/18. The main difficulties seem to be the large diameter of the scion versus the small diameter of the seedling root-stock and the scion cambial/bark interface is undulating which prevents true alignment of cambial tissue between root-stock and scion. None of the grafts were recorded as having survived by early December 2018.

### Grafting & budding trial 3

Mature scions were collected from 4 trees (3 *C. indicum*, 1 *C. harveyi*) from Tongoa on the 4/12/18 and used on the 5/12/18 for grafting and budding onto seedling root-stock at Tagabe nursery. A total of seven top-wedge grafts and nine bud-grafts were made onto seedlings remaining in the nursery from the 2017 collection. These seedlings had been affected by the leaf fungal rot and were not in a very good condition.

Initial reports from DoF staff were that there was some success. The grafts were assessed in Jun 2019 and none from either the budding or top wedge treatments were successful (Figure 3 and Figure 4). This result does not necessarily mean that it is not possible to graft mature buds onto juvenile seedlings, because the low quality of the rootstock may have influenced the result. Further grafting and budding experiments are required to evaluate this method of capturing wild sourced plant material.



**Figure 3: Preparation of mature scion buds (left) and budding technique onto seedling rootstock used for *Canarium* collected from Tongoa (Dec 2018).**



**Figure 4: Unsuccessful bud grafts using mature *Canarium* buds grafted onto nursery seedlings. Grafts were made in Dec 2018 and assessed in Jun 2019.**

#### Grafting & budding trial 4

Grafting was trialled using material collected from a trial orchard established in Innisfail (Australia) over 20 years ago putatively derived from seed collected from PNG. Seedlings were germinated from this source for use as rootstock in October 2017 and used for grafting in June 2019. A total of 12 top-wedge grafts and 12 buds were taken (Figure 5 and Figure 6). The scions of both methods survived for at least 6 weeks before finally succumbing.



**Figure 5: Mismatch in diameters between mature scions and seedling rootstocks with cambial layer aligned on one side only. The scion on the left was left 'as is' when grafting, while the scion on the right was trimmed to the size of the rootstock (Jun 2019).**



**Figure 6: Patch (left) and chip (right) budding performed using mature scion material onto juvenile seedling rootstock, prior to being wrapped in parafilm (Jun 2019)**

### Cutting trial

Cuttings were attempted from seedling tops on the 1/11/18 using inverted water bottles. There was no success primarily because the seal was not watertight and excess water pooled in the bottom of the bottle which ended in rotten cuttings. The process was repeated on 5/12/18 and this time placed on a windowsill inside the DoF research office. No report has been provided on the outcome of this.

### **1.3 Capture selected trees by a combination of clonal and seed-based methods to establish a population for tree selection**

Approximately 6,000 canarium seeds from 81 trees selected for high kernel mass were sown in Santo nurseries (DoF [2,991 seeds] & VARTC [2,973 seeds]) in December 2019 (see activity 1.1.5 for more detail).. Germination at both sites was over 50% with 1776 and 1496 seedlings initially recorded at DoF and VARTC respectively. Due to disruptions in water supply to the nurseries associated with cyclone Harold (Apr 2020) there was an extended period where the seedlings could not be irrigated manually. By June 2020 there were around 740 and 970 seedlings recorded in the DoF and VARTC nurseries respectively. Over the following 12 months all the seedlings at DoF nursery had succumbed. In May 2021 there were close to 500 viable seedlings still growing at the VARTC nursery. Due to unexpected administrative delays, the trial was not established until June 2022.

VARTC provided a suitable site in Santo to plant the Canarium germplasm trial. A trial design was based on the seedlings available in the VARTC nursery during May 2022. The trial was planted in June 2022 by DoF and VARTC staff. The trial represented 37 families planted as 3-tree line plots and each line plot replicated up to three times. Replication was dependent upon seedling availability for the family; where 9 seedlings were available, the family was included in all 3 replicates (18 families), if only 6 seedlings were available then the family was included in the first two replicates (9 families) and a different families

with only 3 seedlings available were substituted for the third replicate (10 families). The trial was planted at a spacing of 3 x 9 m which will allow for the future thinning of each 3-tree family line plot to a single tree with the best (highest yield, kernel mass) tree retained. The expected final tree density at maturity will be approximately 100 to 123 stems per hectare. This SPA when mature can provide DoF and VARTC access to improved seed for their own planting programs and distribution to smallholder farmers and other investors that are seeking to establish subsistence and commercial canarium woodlots (David et al. 2022).

#### **1.4 Evaluate existing *Canarium* crop management methods & develop smallholder-appropriate systems**

A major achievement under this Objective was the preparation of a *Canarium* Production Manual (Grant et al. 2022b). The fledging canarium nut industry now requires strengthening of private sector engagement to scale up the industry and utilise nut resources from existing trees. This manual draws together for the first time information from multiple sources about the industry, markets and commercialisation, biology, seedling and nut production, post-harvest handling, and financial considerations for production and processing. The aim is to provide an easily understood and accessible reference document to a broad range of stakeholders interested in the *Canarium indicum* industry. The manual would be amenable for publication under ACIARs Monograph series. Publication of a translation of the manual into Bislama would benefit greatly its uptake in Vanuatu and is highly recommended.

### **Objective 2: Improve the value of planted sandalwood by widening the deployment of improved genetic resources (~25%).**

#### **2.1 Develop participatory domestication strategy.**

Development and publication of a participatory domestication strategy for Vanuatu *Santalum austrocaledonicum* was a major output of this project. The strategy was initially released as a conference paper at the 2019 Sandalwood Forum in Vanuatu (Doran et al. 2021a) and then published as a research paper in Australian Forestry (Page et al. 2020a).

The amount of the oil-bearing heartwood determines the value of individual trees in the marketplace. This is linked to growth rate, oil concentration and chemical composition (santalol-rich oils most desirable). There is substantial variation in all these characteristics, especially between individual trees within populations but also between populations within and between islands. Much of this variation, particularly of oil characteristics, can be attributed to genetics. Currently, many growers are planting seedlings from non-selected seed sources. This results in less than optimal productivity and market potential for their sandalwood crop.

The domestication strategy developed under this project addresses this problem by proposing a carefully planned and strategically placed breeding program with a 'participatory domestication' mechanism to ensure the improved seed produced is widely available to sandalwood growers. In summary, the strategy builds on the work of earlier ACIAR projects that established a clonal archive of selected trees at Tagabe, Efate and used this as a base population to set-up replicate clonal seed orchards on several islands to provide improved seed where it was most needed. From this departure point the domestication strategy aims to establish new grafted seed orchards firstly using Tagabe clones on at least four islands that are actively planting sandalwood. Two orchards (Summit & Santal Valley) were established on Efate and one each on Tanna and Malekula during the course of this project (see details below).

Progeny trials are to follow to assess the genetic worth of individual clones with the poorest performers culled from the orchards. Only one small (9 *Onesua* families under test at Summit) progeny trial was established during the course of this project (see details below), but it will serve as an important benchmark for future progeny trials to follow. The genetic base of established orchards will be expanded over time by introducing new selections from plantations and the wild in a 'rolling front' breeding strategy (as described in the strategy documents) for each orchard.

Knowledge gaps are to be filled by relevant research and information transfer via a series of technical notes. Technical notes on grafting techniques (Spencer et al. 2018a) and wood grading (Page and Doran 2021) were published during the course of this project.

A Material Transfer Agreement (MTA) was developed during the course of the project. The MTA documents obligations between collaborating parties to allow the transfer of a diverse set of selected *S. austrocaledonicum* clones (based on elevated levels of santalol) from Department of Forests (DoF) Tagabe Nursery to growers participating in the seed orchard program. This was to allow growers to establish a clonal seed orchard(s) on their land(s) to produce improved seed lots for use in establishing commercial plantations in Vanuatu, but with no materials supplied outside of the country. DoF, in addition to supplying clones, undertakes to provide assistance to growers with a planting layout for a seed orchard(s). In exchange, the grower is to provide DoF with data on distribution of improved seed and seedlings (weights and numbers) from their nurseries by recipient and category (small holder grower/ company). MTAs were finalised between DoF and the following growers during the course of this project: Summit Estate (Efate), Andrew Iwak (Tanna), Edmond Julun (Malekula), Santal Valley (Efate) and Erromango Sandalwood Ltd. (Erromango).

A significant achievement under this Objective was the development of a 'Pacific Sandalwood Growers Manual' including country-specific recommendations for planting, marketing and host selection. This guide was based on the highly successful Vanuatu Sandalwood Growers' Manual (Page et al. 2012c), but expanded to encompass a wider range of sandalwood species and conditions throughout the Pacific and incorporates content from numerous local experts from across the Pacific region (Page et al. 2022a).

## **2.2 Establish next generation breeding resources for sandalwood.**

### **2.2.1 Evaluating planted resources of sandalwood for candidate selections**

Key research staff at DoF were involved in the assessment of heartwood to build their capacity to assess the quality of trees that can be used to select superior trees from planted sources throughout Vanuatu. The concept of using surrounding trees as references for growth characteristics was discussed and data collected on tree attributes such as stem diameter, tree height, and form. Distance to proximal hosts (<10m) was also recorded in some of the older compartments at Summit Estate. In addition to tree growth and morphology assessment, candidate trees were assessed for their heartwood production through heartwood coring (Figure 7). The quality of these cores were assessed through GC-MS under the ACIAR project FST/2016/054 for their oil quality characteristics. Eight trees from Summit Estate were selected based on high heartwood development and superior oil fragrant properties and marked for clonal propagation (Figure 8).



**Figure 7: Heartwood cores collected by DoF staff from trees growing at ACIAR host trial at Summit Estate to identify those with precocious heartwood development that may be candidates for clonal selection.**



**Figure 8: Marking of eight candidate plus trees with blue paint and aluminium labels within the ACIAR host trial at Summit Estate.**

### 2.2.2 Propagate existing improved germplasm and candidate selections by seed and/or clonal methods.

The key results from the two grafting training courses undertaken by David Spencer, with the help of Joseph Tungon and Michael Tabi, in September 2018 and then again a year later for different participants were: (1) the building of collaborator capacity to duplicate their grafted seed orchards and capture trees selected from their own plantings, (2) the production of a detailed Technical Note on grafting of sandalwood (Spencer et al. 2018a) and (2) allowing DoF staff to produce small batches of grafted plants from the Tagabe Clonal Archive throughout the project to allow the establishment of new grafted seed orchards (see 2.2.3) with sandalwood growers collaborating with the project. As the top cleft grafting method appropriate to sandalwood propagation is widely used with many crop species the Technical Note is likely to see widespread use generally in training novice grafters.



### 2.2.3 Establish seed orchards, progeny trials and/or genetic gain trials with industry partners.

A small progeny trial comprising of nine open pollinated families (3 from Santo, 2 each from Malekula and Erromango, and 1 each from Aneityum and Tanna) from the Onesua GSO was planted at Summit Estate in July 2018 (Tabi and Spencer 2018). A row-column design of four replications and 4-tree line plots was employed. The most recent assessment of the trial was in July 2020 at age two years. Survival in the main trial was 67% and average tree height was 1.7m (range 0.4m to 3.2m). Despite poor weed control and poor survival in replicates 3 & 4 due, it is thought, to scalping of the topsoil and previous cropping, the growth of some trees in all families exceeds 2m height which is reasonable given the constraints. This trial is too limited in family and tree numbers to provide estimates of genetic parameters but it provided DoF staff with training in establishing sandalwood progeny trials and will be a resource later for studies of the development of heartwood in young trees where their family origins are known.

In ACIAR project FST/2002/098 a total of 40 individual wild sandalwood trees were selected based on their oil quality (elevated levels of santalol). These trees were selected from seven islands of Vanuatu and captured by grafting. They were established in the Tagabe Clonal Archive in 2006/07 as grafted clones. In subsequent ACIAR projects replicate Grafted Seed Orchards (GSO) were successfully established in Ambrym, Efate (x3), Epi, Malekula, Pentecost, Santo and Tanna. There has been some natural attrition of the clones, and currently across all the orchards there are 38 of the original 40 clones selected and 35 remaining in the Tagabe Clonal Archive. The replicate GSOs were established between 2014 and 2020 and generally comprise a subset (18-19 clones) of the 38 selected clones that are currently available. Under this project four new grafted seed orchards were established: Summit Estate (March 2019), Tanna (Dec 2019), Santal Valley (May 2020) and Malekula (Jun 2020). These resources represent a source of improved seed for further research and for growers to establish woodlots in the respective islands and it is important to document and monitor their development and use over time. Details of these and previously established orchards are given in (Page et al. 2022b), and include the location of the orchards, their planting dates, layouts and clonal contents as well as survival counts and cyclone damage if known.

### 2.2.4 Quantify seed distribution from improved germplasm resources.

The seed derived from the GSO sites remain with the landowner who may use the seed for their own purposes or share within their communities. A Material Transfer Agreement is in place for the commercial growers Summit Estate, Santal Valley and Tanna, to ensure the seeds are used to expand their own planted resources and to support the establishment of smallholder plots through any potential out-grower scheme.

Securing information regarding seed distribution from the clonal archive at Tagabe or the other grafted seed orchards (9 GSOs in total) has proved challenging. Data was collected by the GSO owners at Whitewater in Pentecost for a period of six months in 2014 (July to December). During this time 1780 seedlings were distributed to recipients in 51 different villages. During 2018 in Epi, distribution records were maintained for seed derived from the GSO. A total of 32 x 1kg rice bags of sandalwood seed were distributed to 30 individual farmers. Given that a 1kg rice packet is equivalent to ~500g of sandalwood seed, this represents a total of 16kg distributed from the 36 trees (~440g per tree). This equates to an annual production rate of about 16kg or ~62,000 seed for each of the GSOs (~3,900 seeds per kg from Thomson (2006)). When this production rate is replicated across all nine established orchards and the Tagabe clonal archive this represents a

potential for 160kg or 620,000 seed for the improved resources on an annual basis. If a 50% collection rate, 50% germination, 80% plantable seedlings and 80% survival of seedlings after out-planting is assumed, then this represents a potential annual resource of approximately 100,000 sandalwood trees per year from improved sources. At a planting density of 5 x 5, this would represent 250 hectares per year.

Although actual distribution statistics are not available presently for all the orchards there is little doubt that these orchards are being used as sources of seed by local growers and DoF when required. For example, DoF has sourced seed from the VARTC and Onesua orchards for production of seedlings for research (Summit progeny trial) and distribution to local growers. Seed produced by the sandalwood provenance trial and genebank at Navota Farm in southern Santo is harvested almost continuously by local growers such that gaining seed for research from this source has proven almost impossible.

***Objective 3: Enhance knowledge and capacity within whitewood value chain stakeholders, of growing, processing and marketing of high and lower value wood products (~25%).***

**3.1 Conduct inventory of current plantation resource on Santo**

This project aimed to assess the current and future availability of merchantable whitewood timber from plantations across Santo. In order to carry out that assessment the project conducted a review of existing whitewood plantation data and correlated it with available seedling supply data. A set of plots was then selected to cover a representative sample of the estate. At each 500m<sup>2</sup> plot all trees were measured and merchantable (>35cm DBH) trees were described in terms of stem and timber variables. This data has then been used to estimate supply which is given in a report by (Grant and Palmer 2019). There is currently around 30,400m<sup>3</sup> of merchantable whitewood timber on Santo. There are also sufficient numbers of smaller trees that will be growing to a merchantable size to ensure ongoing availability of wood supply over the next decade. A significant proportion (around 65%) of that wood lies within the Melcoffee Sawmill estate at Lorum. The remaining 10,675m<sup>3</sup> exists in small plantings across the east coast of the island. Providing challenges posed by access and market can be overcome, this wood provides a valuable opportunity for potential processors and for growers and, if realised, will desirably demonstrate viability and motivate an upscale in planting.

**3.2 Continue to build the market for structural wood by developing methods of construction and educating builders.**

**3.2.1 Develop management plan for the Timber Research Facility**

The Vanuatu Foresters Association (VFA) is the current manager of the TRF. The VFA have been working with DoF and the Vanuatu Agriculture College (VAC) to organise the reconstruction of the TRF.

The extension to the preservative treatment extension vessel and other items such as fans for kiln drier, sensing equipment for kiln and mechanical properties testing have been shipped from SCU to VFA in Santo in July 2022. SCU staff will travel to Santo in the second half of 2022 to help DoF staff to help commission the TRF on behalf of the VFA..

**3.2.2 Develop grading systems and structural design code**

A visual whitewood timber grading system which sets out minimum requirements for sawn wood products from trees grown in plantations in Vanuatu has been completed with finished graphics (Palmer 2020b). The draft standard was developed in collaboration with Melcoffee Sawmill proprietor Steve Croucher who was able to contribute experience of the

material utilisation and marketing. The specifications are applicable to grading all sawn timber products including timbers for decorative, small and large section structural and utility end uses. The standard utilised strength data and photographic records of break points previously gathered during ACIAR project FST/2012/042 to establish appropriate knot defect sizes for small and large section structural wood. The standard also sought to utilise all wood recovered from a saw log, including pith, large section structural and smaller section utility grade wood. This ensures high utilisation efficiency together with optimum strength of knot included structural grades. This document was provided to DoF in Nov 2020. Feedback from DoF and wood users in respect of the specifications of each grade is required to ratify the validity of the grading system. Consultation with DoF and key industry stakeholders will be undertaken during a workshop planned in the second half of 2022 following the recommissioning of the TRF.

### 3.2.3 Engage engineers/designers to provide building designs that meet cultural conventions and structural demands of weather.

A building design was produced in collaboration with engineers to assist in the construction of a generic single-story, cathedral ceiling, residential timber dwelling. The design reflected Vanuatu indigenous architecture values (Christie 2017) from locally grown whitewood plantation timber. The design document outlines key considerations based on research conducted by the Southern Cross University and Australian/New Zealand residential building standards and was aimed at producing a building design and construction code for Vanuatu. This document remains in development and requires additional strength grading of material graded according to the standard discussed above. Without this data, the specification of member sizes will not be sufficiently definitive to implement the design code. This document will be further refined when the testing equipment at the TRF is recommissioned and sawn timber becomes available for testing.

### 3.2.4 Planning for new demonstration structure(s)

The demonstration building at DoF in Santo was completed to the point of fitting roof sheets during November 2019. A subsequent cyclone (Harold) proved the structure to be sound while adjacent buildings were heavily damaged. The design based on Australian building standards for cyclonic wind loads has proven effective. In the time since cyclone Harold, DoF has completed the building and, according to DoF reports, the building is currently being used as an office, due to the destruction of the DoF offices.

### 3.2.5 Produce materials for construction

The reconstruction of the TRF commenced in June 2021 and it is not yet operational (see activity 4.2.4). Production of whitewood timber will start once the TRF can begin processing again. Start-up of processing is scheduled for the second half of 2022.

### 3.2.6 Construct display structure(s)

The successful preparation of a grading standard and construction code for whitewood was to be demonstrated through the construction of an additional building located in Vila. Unfortunately due to the destruction of the TRF this objective was not achieved during the life of the project.

## **3.3 Evaluate the effectiveness of smallholder-appropriate technologies to improve the durability of whitewood for local-subsistence construction.**

### 3.3.1 – 3.3.3 Review options for low cost chemical treatments and establish trials at appropriate scales to test the efficacy of treatment

A summary of results of this review has been prepared. Calcium carbonate ( $\text{CaCO}_3$ ) sourced from crushed coral and seawater are the main options and appear to offer some potential in providing low cost protection. These methods are, however, ineffective in

addressing the issue of blue stain. Utilisation of whitewood as a village construction material, however, is not impeded by the presence of blue stain.

Based on the results of literature review and work previously done installing above ground durability tests at TRF, the new installations will only include samples treated using  $\text{CaCO}_3$  and will be installed with samples currently in test.

Test samples treated with coral diluted in acid solution were prepared and placed into test with other previously established test specimens, during November 2019. The array of test panels installed at the TRF were lost during cyclone Harold. Regular informal examination revealed no treated panels had been significantly impacted by borers or fungal degrade where they were protected from frequent wetting by rainfall. While there are no definitive results to report, it is possible that good service maybe achieved as building materials within villages and that building to protect from wetting (e.g. wide eaves and installation well above ground splash) and white washing with calcium (coral dissolved in acid) would enhance that performance.

Research was also carried out with six simple chemical treatment options to increase the hardness of whitewood to extend its application in high traffic and impact situations such as flooring (Palmer and Anstoetz 2021). The study evaluated the effect of chemicals with low environmental impact and potentially suitability for industrial-scale implementation in developing countries like Vanuatu. The treatments include (1) citric acid (2) TEOS (3) titanium (iso)propoxide treatment (4) sucrose (5) dry thermal and (6) methyl-methacrylate (MMA) wood polymer. Of the treatments tested, impregnation with methyl methacrylate polymer provided the greatest increase in hardness. Values corresponding with use as flooring were obtained (about 6000 N) that were three times greater than untreated controls. With treatment using methyl methacrylate bulking, the hardness of whitewood can be improved, expanding utilisation opportunities to include markets for flooring timbers, domestically and internationally. This, in turn, will improve investment security in whitewood production and the living standards of small rural landholders.

#### 3.3.4 Analysis of graveyard preservation trials established under FST/2012/042

This activity will be undertaken in the second half of 2022 when SCU staff will return to recommission the TRF with DoF staff on behalf of the VFA.

#### 3.3.5 Preparation of report and extension materials

The preparation of extension materials was aimed primarily at informing stakeholders of processing practices and operation of relevant plant. It is envisaged that this documentation may be prepared as part of a post project activity on resumption of travel.

#### 3.3.6 – 3.3.9 Review low cost timber drying options, construct a dryer and test its capability

A review completed in 2020 assessed glass house designs, local coconut dryers, solar drying which was discounted because of too many cloudy days and hot water systems also discounted because they are too complex and therefore expensive. The availability of sawn-waste wood fuel indicated that this was potentially the best option. A low cost dryer design was drafted based on an insulated wood structure and fireplace. It is envisaged that such a dryer will be constructed at the TRF on Santo post project. Installation of mains power supply will facilitate use of electric fans to provide airflow.

Dryer design was completed in 2020 (Palmer 2020a) but work on construction was delayed due to national inventory and cyclone Harold. Ancillary equipment has been shipped to Vanuatu together with treatment cylinder extension. The timber dryer will be constructed and tested to provide necessary data to refine the design for operation in the Vanuatu context. Operation of this equipment will feature in a processing manual to be

prepared post project. It is also possible that the dryer and other elements of processing can be utilised for training at the TRF.

#### ***Objective 4: Increase adoption of existing technologies for planted forests through improved knowledge development and transfer among stakeholders***

##### **4.1 Improve accessibility of existing knowledge on plantation forestry to increase rates of adoption.**

###### **4.1.1 – 4.1.6 Identify relevant forestry extension materials and local delivery mechanisms and evaluate and adapt the Master TreeGrower Program for application by extension agents in Vanuatu**

A report entitled “Review of extension services in agroforestry and farm forestry and the introduction of the Master TreeGrower Program” has been produced by the project (Reid et al. 2018). This report reviews strategies and actions, under the broad theme of extension, that have, are, or could be undertaken by government, industry and non-government organisations in Vanuatu to engage and support small-holder participation in commercial and community forestry. The report also evaluates the Master TreeGrower (MTG) model developed in Australia and provides assessment of a 3-day pilot MTG course that was delivered in Port Vila in June 2018. The pilot MTG course was attended by 26 participants including farmers and representatives from private companies, NGOs, Government Departments, and educational institutions. The participants and observers involved in the pilot course publicly endorsed the MTG concept and supported the plan for the project to deliver three regional MTG courses.

Three full MTG courses were undertaken by the project: (1) for a canarium grower group of Ni-Vanuatu women at the Avunatari Mission on Malo in October 2018. The workshop was attended by 18 participants (14 from Malo women’s group and 4 BBB (Bisnis Blong Buluk) women’s group); (2) for a whitewood grower group in Santo during April 2019 involving 14 participants (10 male and 4 female) and (3) for sandalwood growers from across the country in November 2019 at DoF in Tagabe with field visits around the island of Efate. This workshop was attended by 56 participants, including 25 smallholder farmers, 10 commercial or joint venture producers, 3 sandalwood licensees, 2 education providers and 16 government employees. Each course was convened by Rowan Reid and engaged multiple, appropriate trainers. Ten DoF staff including leading extension technicians Anne-Marie Sarisets and Judy Kalotap were involved in the courses and received targeted hands-on training in their delivery.

Review reports for the two Santo (Addinsall 2018, 2019) and one Tagabe (Page et al. 2020b) MTG training courses have been provided to DoF. MTG training materials provided were translated from English to Bislama by DoF staff to address one of the main responses from the MTG participants. A concise planning and strategy document based on the recommendations outlined in the three review reports was provided to DoF (Page 2020) to inform the further alignment with DoF perspectives.

This project objective emphasised the engagement of women through the development of women’s leadership teams as a strategy to enhance female skills for income generation, particularly in activities focused on canarium and sandalwood. The conduct of the women-only training event was demonstrated to be highly appropriate as this addressed many factors that can impact on women such as jealousy from partners to attend training that takes women away from their homes, custom requirements that can inhibit women from public speaking if male relatives or husband is present and general overall shyness or reluctance to speak in front of men. To further encourage the involvement of women in extension training consideration for the following is recommended: (1) conducting women-only wherever possible having Ni-Vanuatu women conduct the training, particularly as lead trainers, (2) empowering more Ni-Vanuatu farming women to share skills they had learnt through the ACIAR projects by becoming trainers themselves and (3) ensuring the

training has relevance to the livelihoods of Ni Vanuatu women, even if it is not necessarily focused on project objectives (Addinsall 2018). Vanuatu female participants that participated in both mixed-gender and female-only MTG training voiced their preference for female only training, suggesting it was less intimidating when male participants were not present, particularly highly regarded male Ni Vanuatu farmers (Addinsall 2019).

Participants rated the MTG program highly for improving their knowledge across 11 forestry knowledge domains and responded well to the applied nature of the MTG 5-day program. Participants that responded considered that more hands-on training aspects be considered for some of the technical aspects such as pruning and grafting in future programs or activities. All participants consulted their peers (friends) for forestry information, suggesting that DoF can play a role in improve the 'quality of conversation' among peers on the subject of forestry to enhance the efficacy of peer based exchange. The effectiveness of the peer-based knowledge transfer between MTG graduates (island-based groups) will depend on the level of support for follow-up activities that bring the group together, since participants have limited resources to host and visit distant farmers. Island-based tree grower groups can be used as the basis for train-the-trainer activities so that participants become integral to the function and sustainability of the group.

It is clear DoF considers the MTG an important extension tool for connecting tree farmers and building local capacity to establish, manage and market their woodlots. Plans to adapt the Master TreeGrower Program for application in Vanuatu has been considered by DoF extension agents. While they have confidence in being able to deliver such programs in the future, they remain dependent upon adequate funding support. Linking such training events and ancillary meetings with other programs supported by the Ministry of Agriculture (MALFBB) such as the agricultural shows that are held among the islands can offer a way to reach existing and prospective growers within current budgetary allocations for forestry extension. DoF plans to hold its own version of the MTG in September 2022 in Tongoa

#### 4.1.7 Improve accessibility of existing knowledge in plantation forestry through radio, print and social media

Much was achieved for this activity through the engagement of Ginny Stein, a veteran Australian journalist and filmmaker, through her posting as an Australian volunteer endorsed by the ACIAR project. While at the Department, Stein provided training in multimedia, which included photography, video recording and editing, and social media. The latter training included techniques for crafting engaging social media posts and the use of commercial promotion advertisements to target stakeholders in Vanuatu. One of the training events included 50 participants that were brought from around the islands to Port Vila as part of the Forest Inventory training. Officers were trained to take video using their mobile phone cameras. This effort culminated in the production of a documentary 'Life and Limb' which follows a team of DoF staff during implementation of an inventory of the forest lands on twelve islands. It was released at the 2020 Eugene Environmental Film Festival and on social media and shows the importance of forests in Vanuatu culture and how logging for several decades has affected the ecological balance in the country's small islands.

Stein's contribution also extended to the production of a series of eleven short videos in collaboration with the DoF, which were promoted through their Facebook page. This series called "Gudfala Tri Blo Mi". highlighted the importance of eight priority tree species. This was done through interviews with individual villagers who explained their fascination for a particular tree species. During the life of the project the DoF Facebook following increased from 500 in mid-2017 to 4,200 in mid-2021 so this proved a very effective way of disseminating information pertaining to Vanuatu forestry.

#### 4.1.8 Evaluate the effectiveness of stakeholder engagement with delivery of MTG-like training by DoF extension agents.

The effect of the MTG on its participants was assessed, documented and ultimately contributed to a research publication (Addinsall et al. 2019). Participants, both male and female, provided strong support for verbal farmer to farmer information exchange over participating in workshops or training days with project and government staff/extension workers. When further explored in focus group discussions, it was clear that government extension initiatives were limited in their contact with smallholder farmers. Participants in the training also communicated that they preferred to observe practical examples of the work from other farmers through demonstration sites. This very practical and peer-based approach would give them greater confidence that such options were applicable to their own situation. With the arrival of the pandemic and resultant travel restrictions, it was not possible to complete the planned monitoring and evaluation of the participants over the medium term.

### **4.2 Build industry capacity to understand and manage key aspects of the timber industry value chain.**

Local processors that were setup for, and continue to utilize, large native forest saw logs, have not transitioned to processing planted whitewood. The project design, which incorporated establishment and operation of processing systems for planted whitewood, was intended to lead to trade in sawn whitewood overseen by the VFA. With the commercial potential of planted whitewood demonstrated to growers and other stakeholders in domestic markets, this outcome was envisaged to lead to further plantation establishment. An inventory of resources on Santo indicated the presence of several years of sustained primary resource supply to support this strategy while new resources are established. A priority for the TRF is to establish an operation that is efficient enough to set farm-gate prices to reflect the costs and conditions for growing plantation timber. Developing processes, and thus markets, for thinnings would incentivize the application of optimal silvicultural practices, increase the financial returns of planting for farmers, and yield returns earlier in the growing cycle. In addition, the DoF should play an active role in the geographic planning of future plantations so that the available estate is located near established processing facilities. Harvesting woodlots will be more economical to portable saw millers when woodlots are close together, due to a reduction in cost of moving the portable mill between woodlots (Carias et al. 2022b)

### **4.3 Develop locally appropriate business models for sandalwood, whitewood and canarium**

#### 4.3.1 – 4.3.2 Undertake financial analyses for sandalwood, whitewood and canarium and simplify use and improve adoption by project partners and stakeholders

**Sandalwood** - The research evaluated the financial performance and risk of producing high-value sandalwood products and the suitability of existing lending opportunities to such an activity. Results show that smallholder sandalwood can be a profitable investment, but tree security issues and environmental risks are leading to early harvest and an associated 64% reduction in potential returns. To improve the profitability and attractiveness of sandalwood plantations to smallholders, the following key issues must be addressed: (i) risks associated with tree theft need to be dramatically reduced; (ii) earlier returns from planting systems must be planned for smallholders with more immediate needs; and (iii) greater access to financial services is needed, including loans with competitive borrowing rates, particularly to increase the scale of planting for individual smallholders that might be constrained by labour. Theft mitigation can include fencing, patrolling, microchip tagging, all of which add significant maintenance cost. Formalised

social and governance structures within and between villages, may be more cost-effective in improving tree security. Incorporating agricultural crops into systems helps produce earlier financial returns, and more rapid payback. Accessible loans can allow for upscaling of smallholder systems that are limited to household labour for plantation management, harvesting, and processing the logs (Ota et al. 2022b). The sandalwood model has been developed as an online user-friendly interface, which allows potential investors to modify some key assumptions <https://sites.google.com/site/agroforestrytreeproducts/>.

**Whitewood** - A paper was prepared 'Making whitewood tree growing financially attractive to smallholders in Vanuatu (Ota et al. 2022a). This paper assesses the potential of smallholder whitewood tree growing for the development of the industry in Vanuatu. The specific objectives were to: i) carry out a systematic review of available literature on whitewood, with a special focus on Vanuatu; and ii) perform a financial analysis of small-scale whitewood tree plantations to understand the conditions under which the investment is profitable to smallholders. The literature demonstrated that whitewood has desirable environmental and socioeconomic features and that the bottlenecks for widespread whitewood growing by smallholders may be related to issues beyond technical ones. Results of the financial analysis indicate that the breakeven prices for smallholder-grown whitewood are much higher than prices paid for native harvest. The breakeven price for a model with long rotation is attainable, but long rotations are unlikely unless threats to tree plantations and the need for more immediate income are addressed. Collective sales can be financially viable if buyers can accommodate an increase of 7-16% in price for larger volumes and more consistent supply. The combined findings from the literature review and the financial analysis indicate that upgrading the smallholder whitewood value chain is required for the development of the industry.

**Canarium** - An assessment of the potential of *Canarium indicum* L. plantations for smallholders in Vanuatu supported by this project resulted in a paper 'Canarium nuts for supplementary household income in Vanuatu' (Ota et al. 2021). It was based on a review of available literature on canarium nuts in Vanuatu followed by financial and sensitivity analyses of canarium tree plantations at the household level under four scenarios: sale of nut-in-shell, sale of kernel-in-testa, sale of dried kernel using solar dryer, and sale of dried kernel using electric dryer. The literature demonstrates great potential for the canarium nut industry, but also highlights its challenges, which were confirmed in the financial analysis. The financial returns for the different scenarios, the nature of labour provided, nut processing limitations, and potential market opportunities are discussed in the paper. Current prices do not pay off investment in canarium growing if labour is costed at the minimum wage of the country. However, smallholders might place a non-financial value to the activity. Prices paid for all canarium products or labour efficiencies for processing must increase for a profitable investment. There is potential for value adding if infrastructure is available and if smallholders are interested. The paper highlights that the challenges and opportunities for canarium nuts are also relevant for non-timber forest products in other remote locations in the tropics.

#### 4.3.3 Develop broader business models for the three species.

A report entitled 'Challenges and opportunities for inclusive value chains of forest products in Small Island Developing States: canarium nuts, sandalwood, and whitewood in Vanuatu' (see Carias et al. (2022a)) was provided to DoF in Jun 2021 for input. Carias et al. (2022a) explores the potential for developing niche forest product value chains that are inclusive of small-scale producers in the island nation of Vanuatu. Using existing academic and grey literature and on-site research for three forest products, the report describes the current situation with the industry, and then proposes inclusive value chains (IVC) that improve on the business-as-usual scenario. Although market analyses confirm the potential for smallholders to benefit from participating in niche product value chains, difficulties inherent in sourcing from smallholders, which are intensified in SIDS, must first be overcome. Problems such as small production volumes in numerous dispersed plots



with difficult access, high transport costs, low technical know-how, difficulties in accessing inputs and finance, unreliability of supply in terms of quality and quantity, and lack of reliable information about the resource base hinder IVC development. Increased vertical and horizontal coordination within the value chains address many of these issues, but in the Pacific context, some forms of coordination may be more feasible than others. The Pacific region does not have a strong cooperative tradition, so temporary horizontal coordination, long-term agreements, and contracts between producers, processors, and buyers may be necessary to make IVCs for niche island products achievable.

#### 4.3.4 Develop domestication strategies for canarium and whitewood

Domestication strategy documents for both canarium (Macdonell et al. 2022) and whitewood (Doran et al. 2021b) were completed during the course of this project and have been provided to the DoF for their use and implementation.

**Canarium** – Macdonell et al. (2022) outlines a breeding plan using the biological resources and characteristics of the species as well as physical and human inputs to affect genetic improvement. This will be achieved through efficient selection and mating to increase plantation yield from utilising trees with high mass kernels. Two options are canvassed, of which the first can commence with no additional research, and the second that requires cloning to capture selected trees and transfer them into clonal breeding gardens. Option 1 requires an extended timeframe to realise gains but requires relatively low investment. Option 2 is reliant upon developing solutions to current knowledge gaps in cloning methodologies and controlled pollination, and is more resource dependent to achieve results. The strategy document is structured by outlining relevant knowledge gaps, and previously identified issues for the production, processing and marketing of canarium. It defines the basic concepts of the strategy, the resources required to implement it, the steps for Option 1, the steps for Option 2 and flowcharts illustrating the main activities on a timeline. Timeframes and the expected level of improvement available at each stage of the breeding plan are estimated. It is then concluded by highlighting research needs and germplasm delivery pathways.

**Whitewood** – Doran et al. (2021b) outlines a strategy of participatory domestication to implement plant breeding to continue improvement in this species and deploy improved germplasm to smallholders and commercial plantings. This program builds on the work of (i) SPRIG that first sampled natural stands to establish a provenance/progeny trial at Shark Bay (Santo) and (ii) ACIAR project (FST/2008/010) that characterised genetic variation in key traits and made selections for establishment of two second generation progeny trials. The document first summarises what is known about the species as it pertains to breeding strategy. Much of this information has been generated by the earlier projects and included are maps of trials, seed lot rankings and details of genetic analyses so as to fully inform future tree breeders working on the species. The information is brought together into a breeding strategy complete with a proposed work plan. The strategy proposed is largely conventional (recurrent selection with open pollination) but some innovation (cloning and controlled pollination) is suggested as is research needed to fill knowledge gaps if future resources allow. The document concludes with a description of trial plots on several islands that were established during the last project as a source of improved seed and a demonstration to local communities of the benefits of using improved seed. The uptake of seed and knowledge remains to be assessed.

## 8. Impacts

### 8.1. Scientific impacts – now and in 5 years

**Canarium** - The surveys to characterise canarium nuts across eight islands in Vanuatu have led to greater understanding of the variation present, phenotypic correlations between important commercial traits and the key traits for selection (Grant et al. 2022a; Macdonell 2017, 2018, 2019). The results will assist greatly in the domestication of the species to produce forms that are desirable for planting in commercial agroforestry systems. The research trials on grafting and budding to allow selections in the field to be transferred to breeding populations were unsuccessful confirming that this species is difficult to propagate vegetatively by conventional methods, but pointing to the need for further work. Seedlings from 37 families selected during the surveys for high kernel mass were planted in a base population at VARTC during May 2022. This trial will be an important resource for study of variation in commercial traits in 'plus trees' and could be converted into a seedling seed orchard in the years ahead following the recommendations in the domestication strategy (Macdonell et al. 2022). Much research undertaken on canarium in this project has been incorporated into a Canarium Production Manual (Grant et al. 2022b). The scientific impact of this manual can be amplified through its potential publication and distribution as an ACIAR monograph. This manual is a first time collation of all available information about the industry from species characteristics to production and marketing aspects to provide an easily understood and accessible reference to a broad range of stakeholders interested in the *Canarium indicum* industry.

**Sandalwood** - Two peer-reviewed papers (one conference and one Journal) describing a participatory domestication strategy for Vanuatu sandalwood were published during the course of the project (Doran et al. 2021a; Page et al. 2020a). These review the research (including selection of wild trees based on oil properties, grafting methods, what is known about floral biology) and other activities (establishing grafted seed orchards on multiple sandalwood-growing islands, establishing the first progeny trial and grafted seed orchards under MTA agreement with major growers) that have been done by this and earlier projects towards improving yield of sandalwood plantations in Vanuatu. These publications provide a scientific grounding for ongoing research and development: their impact in five years' time will be realised through the adoption of the recommendations.

The project was also responsible for a peer-reviewed paper on product specifications for tropical planted sandalwood to facilitate transparent commerce and trade (Page and Doran 2021). This document represents a first-time standardised system for the grading of smallholder planted sandalwood products. It aims to inform and empower growers of the likely value of their wood grades when negotiating prices with sandalwood brokers and is likely to have immediate impact as it fills an important information gap. Another shared-project output certain to give substantial impact is 'The Pacific sandalwood: growers' guide for sandalwood production in the Pacific' (Page et al. 2022a). It is an evolution of the Vanuatu grower's guide to cover other countries cultivating sandalwood species in the Pacific (e.g. Fiji, Papua New Guinea, Timor-Leste, and Tonga). The guide aims to educate often isolated growers of optimum silvicultural practices with their species. It has been published by ACIAR and it is projected that local translations will be made to increase its potential reach and impact.

Technical reports produced by the project include one on grafting techniques (Spencer et al. 2018a) which documents optimum procedures for top cleft grafting of sandalwood and one giving details of the grafted seed orchards established on multiple sites by this and earlier ACIAR projects (Page et al. 2022b). Both reports are excellent resource documents for tree breeders who follow and will deliver impacts now and into the future.

**Whitewood** – The whitewood domestication strategy outlined by Doran et al. (2021b) that summarises all relevant knowledge on the species as it pertains to tree breeding will serve

as an essential resource document for future projects aimed at the genetic improvement of whitewood. It is important that this strategy is implemented as whitewood germplasm, as now in use in agroforestry plots, is seen to be of less than optimum form and growth rate. Use of seed from selected trees in the first generation orchard at IFP will result in better species' performance and this can be improved further by development over the coming years of the Bombua second generation family trial into a second generation seedling seed orchard.

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## 8.2. Capacity impacts – now and in 5 years

The most substantial capacity building activity during the project was delivery of the Master TreeGrower Program as a model for future forestry extension activities in Vanuatu. The pilot and the three full MTG courses involved 26 and 88 participants respectively. Participants included farmers and representatives from private companies, NGOs, Government Departments, and educational institutions. Feedback from participants within the MTG program clearly demonstrated a need for forestry extension with most rating their knowledge as low to moderate across 11 knowledge domains. The feedback following the workshops equally demonstrated that the MTG to be an effective mode for improving confidence with knowledge across the same domains being assessed as high to very high. Ten DoF extension technicians were trained during the delivery of the MTG receiving valuable hands-on training. This included leading extension agents Anne-Marie Sarisets and Judy Kalotap who were heavily involved in the planning, implementation and follow-up of the MTG Program. DoF management has viewed the program favourably for its capacity to engage growers across the value chain rather than focussing on just one aspect such as planting. DoF has plans for implementing a MTG-like forestry extension program in Vanuatu with their first event being held in Tongoa in September 2022. This shows that the MTG was successful in developing extension expertise among DoF staff to independently deliver the program for a range of stakeholders.

The project supported a large contingent of DoF Forestry Officers and sandalwood industry participants from Efate and the outer islands to participate in the 2019 Sandalwood Regional Forum. This offered Vanuatu industry the opportunity to showcase their advances in both research and industry development to an international audience. Vanuatu's hosting of the forum also facilitated information exchange through both formal sessions and informal field interactions. This culminated in a group study tour to Tanna that included both project-supported Vanuatu participants and researchers from allied ACIAR projects in the Pacific. This event offered networking opportunities for both research and business and was reflected in the positive participant responses across international and Vanuatu-based participants (Page and Kalsakau 2020). The delivery of the Forum was only made possible through its partnership with this ACIAR project through the dedication and support from Toufau Kalsakau as the in-country DoF project manager at that time.

The forum offered opportunity for developing writing and editing skills among project staff and Toufau was a successful editor of the proceedings and final report for the Forum. Australian staff mentored a number of DoF officers as authors and co-authors on research papers written for the proceedings including Rexon Viranamangga, Godfrey Bome, Toufau Kalsakau, Mesek Sethy, Joseph Tungon, Michael Tabi and Hanington Tate. Some of these papers would then be further developed into peer-reviewed papers that were submitted or published during the project.

The project has undertaken a number of capacity building and training activities focused on development of skills in grafting sandalwood, sandalwood plus tree assessment, the preparation of establishment reports for research trials and utilisation of plantation grown whitewood for timber production. Two courses (2018 and 2019) in optimum sandalwood grafting techniques were delivered to DoF and industry participants during the course of the project. These were instrumental in ensuring a steady supply during the project of

sandalwood grafts for establishment of additional (4) grafted seed orchards. In-field practical training was conducted with DoF staff for surveying and undertaking sandalwood tree sampling to identify plus trees. This culminated in the identification of eight plus trees at Summit Estate that could be added to the clonal archive.

With retirement of long-time and esteemed DoF researcher Joseph Tungon during the project it was evident that capacity building of remaining research staff was required, particularly for report writing. David Spencer provided one-to-one training in 2018 on preparing establishment reports with the Summit sandalwood progeny trial used as the model. Additional training was undertaken with staff during the production of the Canarium progeny trial establishment report. With an improvement in the quality of the reports being evident over the course of the project, ACIAR has contributed to upgrading staff capacity in this area which will positively impact the quality of reporting future projects.

The development of processing capacity appropriate to plantation-grown whitewood can provide an additional product for landholders that requires minimal inputs, but has the capacity to yield substantial cash injections to village economies. Additionally, the resource can relieve significant pressures on native forest wood supply that is already depleted. There are downstream benefits of employment opportunities in secondary industry that will provide opportunities for training in technical trades that include wood processing as well as supporting maintenance industries such as mechanical repairer and metal fabricators. Likely the most important output in the future will be the capture of at least part of the domestic market for building timbers, which is currently supplied by imports of softwood. This will assist to balance international trade and retain investment revenues in country.

ACIAR supported VDoF researcher Toufau Kalsakau to secure a John Dillon fellowship in February 2020. This fellowship equips awardees with leadership and management capacities for conducting natural resource-based research for development. Toufau attended training in Canberra, followed by a study tour of The University of Sunshine Coast research programs as well as other agricultural research initiatives in north Queensland. When Toufau's return home to Vanuatu was delayed, she undertook a certificate level four in entrepreneurship at USC. Following her four month extended stay in Australia, Toufau returned to the role of senior researcher for a further 6 months before being transferred to the Operations Section within DoF.

With all DoF researcher roles in Port Vila vacant for almost twelve months, USC subcontracted May David to fill the role of Senior Researcher from late 2021 to the conclusion of the project in June 2022. She came to the project with a Bachelor of Science (Environmental Science), but limited exposure to production forestry. The project supported May to transition to this new role with remote capacity building and she has performed exceptionally in the position. May has demonstrated a capacity for budget management, staff communication and management, technical work and report writing.

An issue in capacity building outcomes that was reported in the Final Report of FST/2016/158 in Fiji and Tonga has also been experienced during this project. Many of the DoF staff who receive training are only temporary employees and are, because of their short tenure, not able to make practical use of the learning to the benefit of their organisation and the project. Loss and transfer of experienced research staff has also had significant consequences for implementing ACIAR projects. There is a need to support DoF in research staff succession planning so that minimal loss of institutional expertise occurs when individual staff members retire or are transferred within the organisation.

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### **8.3. Community impacts – now and in 5 years**

The project has facilitated some important community initiatives, which will have a positive impact on their capacity for high value smallholder forestry in the future. A total of 114 tree

growers across three forest crops (canarium, whitewood and sandalwood) and multiple islands received training under the Master TreeGrower (MTG) Program provided by this project. The MTG Program aims to extend the knowledge and support networks of participants by providing: information about growing their priority species, markets and technologies; skills training in tree measurement, silviculture and management; and, the opportunity to share their experience with other local tree growers. Participants expressed interest in forming tree grower groups both within their village and more representative groups for their islands for information sharing following training. With DoF planning to implement a MTG influenced extension initiative, there is potential for positive community impacts for adoption of productive subsistence and commercial forestry woodlots.

The sandalwood GSOs established on five northern islands of Vanuatu are now delivering improved seed for the benefit of local sandalwood growers. Although seed yields and distribution of seed amongst growers is available for only two of these orchards (Pentecost and Epi), there is evidence that local communities are using these resources as a source of improved seed. For example, failed attempts by DoF to collect seed in the sandalwood gene conservation planting at Navota Farm are because community members surrounding the planting are getting there first. In the next few years the GSOs established as part of this project will be producing seed similarly.

The training in grafting sandalwood provided by David Spencer in Efate (Tagabe forestry nursery and Santol Valley) in 2018 and again in 2019 was highly successful. Following this training, DoF staff were able to carry out the grafting needed to establish the GSOs at four sites (Summit Estate, Santol Valley, Tanna & Malekula) with a high level of success. Other multiple participants of these training courses, if not able to apply their newly learnt skills in grafting sandalwood, will be able to use these skills in grafting a wide range of crop plants as requirements are transferable between a wide range of species.

The production processing and marketing of whitewood offers a significant opportunity for community development in terms of building skills and capacity in primary and secondary industries. This in turn can drive growth in educational opportunities for young people. In addition, the income from whitewood and the “banking” of revenue as standing forests, offers landholders and the wider community and opportunity to control the provision of cash over time building resilience into the rural economy. For example, a harvesting event of suitable size could provide one off income that could buy a motor vehicle, or fund acquisition of resources or education service to improve the livelihood and standards of living for rural communities.

### **8.3.1. Economic impacts**

The improvement in availability and quality of sandalwood seed through the grafted seed orchards established by this and the former ACIAR project would be starting to have an impact on farmer’s incomes in the northern islands where formerly seed was in very short supply with no account taken of its genetic quality. Incomes will only increase as sandalwood crops established with seed orchard seed mature. These crops receiving the correct silviculture can confidently be expected to grow faster and yield greater volumes of heartwood that produces an oil higher in the santalols required by the market. Vanuatu sandalwood harvest attained 170 tonnes in 2021, which were harvested from planted stands (DoF data 2022). This represents the highest yearly harvest since 1987 and a substantial jump from the 10-50 tonnes annual harvest over the past ten years. This is sound evidence of the economic impact from the series of ACIAR investments into sandalwood improvement and agroforestry. While this confirms the long period for economic impacts to accrue, it does give first indication of the substantial impacts on local livelihoods expected to occur in the coming years. The sandalwood grading system developed in this project offers scope for immediate economic impact by improving transparent trade so that growers are paid fair prices for their product. DoF have committed to review their current 3-grade system in consultation with industry stakeholders to ensure maximum value can be secured for their stakeholders. The

grading system proposed through this research project will be used as the foundation for that consultation.

The financial analyses of the three priority crops (canarium, sandalwood, whitewood) show that, at the current prices, canarium and whitewood products require attention to production efficiency and/or price structure reform to realise their full economic potential. These studies show that canarium and whitewood industries can be profitable to small holders with value chain interventions and improvements. The challenges and opportunities for these industries discussed in these manuscripts will inform their future development to the benefit of smallholder farmers and the national economy. The analysis for sandalwood revealed that the financial performance of this crop is highly sensitive to the length of the rotation. With sandalwood growers keen to make a return on their sandalwood investments, they take a significant financial hit (64% reduction in potential returns) when they sell them prior to maturity. The financial modelling research gives DoF the information in which to guide appropriate harvesting sizes that could be incorporated into a revised grading system. This would have substantial economic impact for resource holders as their sandalwood plantings get closer to maturity.

Farming systems in Vanuatu are typically comprised a mixture of agricultural crops and trees for both household use and sales and canarium, sandalwood and whitewood can be incorporated into such systems. The shortcomings for the development of these industries lie, in part, on the low adoption of silvicultural interventions (e.g. pruning and thinning), low returns achieved (often due to suboptimal silviculture), the nature and risks associated with such investment (e.g. damage from frequent cyclones and theft), the scale for processing and marketing constraints. Training for growers is an excellent means of addressing these shortcomings and this project has introduced the Australian Master TreeGrower (MTG) Program to Vanuatu as a model for future DoF extension activities. The further evolution of this program to suit Vanuatu conditions and its widespread deployment will lead to a positive economic impact by improving woodlot silviculture management and a greater understanding of markets.

### **8.3.2. Social impacts**

An objective (4.1.2-Empowerment of women) of this project was to assess the engagement of rural farming Ni-Vanuatu women through peer-mediated learning based on the MTG Program as a strategy to enhance female skills for income generation, particularly in activities focused on canarium and sandalwood. The findings of three studies (see Addinsall 2018, 2019 and Addinsall et al. 2019) strongly support female farmer-to-farmer strengths-based and interactive training as a strategy to better engage women in ACIAR projects. This approach respects that women's priorities may differ from the technical and commercial focus of many development projects. The obvious preference for female-only training was based on participant lived experience that it was less intimidating when male participants were not present. Research also showed that positive impact would be amplified further through building and engaging female leaders to play a prominent role in convening these extension interventions. The future deployment by DoF of female only extension teams when working with Ni-Vanuatu women farmers will have positive training and societal benefits.

### **8.3.3. Environmental impacts**

Promoting planting of the projects three priority species has positive environmental impacts as it reduces the pressure on already scarce natural stocks, protecting the species and their continued traditional uses. This is especially the case for Vanuatu sandalwood and whitewood. The establishment of domestication strategies for the three species will improve woodlot profitability while helping to ensure that genetic diversity is conserved, thereby protecting the species' from further genetic degradation. Positive

environmental impacts can be added to the brand of Vanuatu forest products to promote niche markets.

The project has advocated the planting and economic development of the native *S. austrocaledonicum* rather than the exotic introduction, *S. album*, from India and Indonesia. *S. album* poses a threat to *S. austrocaledonicum* as a “genetic pollutant” and could undermine attempts to build a niche market for pure Vanuatu sandalwood products.

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#### **8.4. Communication and dissemination activities**

The project produced a range of formal and informal publications (see Section 10.2). There were 12 formal publications (4 journal articles, 4 book/chapters and 4 conference papers) produced during the course of the project. A further seven reports are currently being prepared for publication submission. The published ACIAR Sandalwood Monograph and the proposed Canarium monograph are of particular significance for extension practitioners and smallholder producers. They bring together information on all aspects of growing, processing and marketing these crops in easily understood, comprehensive manuals. They will lead to better silviculture, higher yields and better returns from these crops for small-holder growers. The participatory domestication strategy for Vanuatu sandalwood featured in two papers brings together information pertinent to the genetic improvement of this valuable species and how it is proposed to involve small-holder growers in hosting seed orchards and distributing improved seed. In addition, a series of 18 technical and field reports have been published to support this project. Domestication strategies for canarium and whitewood are notable amongst these for their likely economic impact when fully implemented.

The videos produced by Ginny Stein ('Life and Limb' on the work of DoF and the series of 11 short videos 'Gudfala Tri Blong Mi' [My Favourite Tree]) for the project and published on social media were very well received by the public. A recommendation from participants in the third MTG Program was that DoF should continue with the 'Gudfala Tri Blong Mi' video series as a way to support independent peer-based exchange of forestry information.

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## 9. Conclusions and recommendations

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### 9.1. Conclusions

The resource characterisation of canarium has provided the foundation to enable the industry to move forward with a population base selected for large mass kernels. The progeny trial established will provide the opportunity to investigate some of the many knowledge gaps on the biology of species. In particular, within family variation, stability of kernel mass between years, prevalence of single or double kernels and flowering phenology. Clonal multiplication through grafting and cuttings proved unsuccessful using the available infrastructure, and future attempts should be undertaken under controlled conditions where environmental variables can be more accurately controlled. A domestication strategy for canarium considered both current technology as well as yet-to-be developed methods so that species improvement can be achieved by using either seed-based or clonal methods. Data and information gathered during the fieldwork facilitated the production of the canarium growers manual, which summarises all the available information about *Canarium indicum* across its natural distribution and has been published as an ACIAR monograph.

Five of the nine grafted seed orchards (GSOs) of sandalwood across seven sandalwood-growing islands, established between 2014 and 2020, are now producing seed with evidence that this seed is in strong demand by local growers. This seed has the potential to be higher yielding in heartwood production, oil concentration and oil quality which should deliver economic benefits to growers. This program should be extended to other sandalwood producing islands like Erromango, with more replication on the larger islands like Santo and Malekula, so that seed of better genetic quality is readily available. The avenue for achieving higher gains from this program is contained in the participatory domestication strategy for Vanuatu sandalwood. This strategy should be used now as the blueprint for new sandalwood GSOs and upgrading of the best of the earlier plantings. The entire GSO program is based on the Tagabe Sandalwood Clonal Archive comprising 38 of the original 40 clones established. The Tagabe Archive should be expanded and further renovated by applying optimum silviculture to conserve the genetic resource and produce abundant high quality grafting wood (scions) for new orchards. The Pacific sandalwood grower's manual, produced by the project, in collaboration with ACIAR projects FST/2016/158, FST/2014/069, FST/2016/024 and CIM/2014/082, is a major achievement and will assist growers across the wider Pacific region.

A domestication strategy was developed for whitewood as part of this project. It was a substantial activity as it was drafted as a one-stop-shop for all available information pertaining to the genetic improvement of this species in Vanuatu. The idea being that tree breeders to follow can quickly understand the work that has gone before and the basis for the breeding strategy proposed. The genetic resources established by the previous project, which are the starting points for the new domestication strategy are beyond the current DoF budget allocation for their ongoing maintenance. The first generation whitewood seedling seed orchard at IFP Santo should be the only seed source used to grow seedlings for distribution to smallholder farmers so that their efforts are concentrated on faster growing and better formed trees. It is obvious from the poor form of many of the farmer plantings that alternative sources of seed are being utilised and this needs to be rectified as soon as possible.

Inventory indicated a sustainable supply of whitewood sawlogs of varying quality, of at least 500m<sup>3</sup>/annum was surveyed on eastern Santo. This resource can provide sufficient initial wood flow to develop and maintain a secondary processing capacity supplying decorative and structural timbers to domestic markets. Work on a strategy to establish processing capacity at a small scale to support continued whitewood production in plantations continues. Expanded preservative treatment capacity along with new waste-



wood-fired drying facilities will provide the necessary opportunity to establish a permanent wood flow in a value chain. Ongoing work delayed by travel restrictions during the COVID-19 pandemic, can enhance this initial output by producing grading and building technical documentation, however this will depend heavily on stakeholders in country exploiting opportunities enabled by the processing capacity established by this project.

Whitewood utilisation has been extensively researched with solutions designed to enable commercial exploitation of plantation grown whitewood. This capacity in turn has potential to greatly enhance opportunities for rural communities in terms of potential diversification of income as well as expanding employment opportunities in technical trades and commercial marketing. Finally, plantation grown whitewood can reduce pressure on native forest resources, while maintaining extensive use of wood that is customary in Vanuatu.

Training, modelled on the Australian Master TreeGrower (MTG) Program, and trialled with different Ni-Vanuatu farmer groups showed that it was an appropriate model for DoF extension activities, after modification to meet Vanuatu requirements. Bislama to be employed throughout and delivery by all-female extension teams when Ni-Vanuatu women's farmer groups are being trained were some of the key recommendations from participants in the trials of MTG.

The financial and value chain analyses undertaken by the project provide a contemporary appraisal of their structure, function and commercial value. They have for the first time brought all the variables effecting the economic performance of the three industries (canarium, sandalwood and whitewood) into interactive, species-specific spreadsheets where variables can be changed to determine their influence on financial performance. Despite the canarium and whitewood industries having structural issues for their profitable production and the financial performance of the sandalwood industry being influenced by harvesting time, the analyses show that with achievable changes each industry can be financially sustainable for smallholder growers.

The project met all of its Australian milestones. In addition, many of its Vanuatu milestones directed at domestication of the three priority species, adoption of results and communication were largely achieved. This is a significant achievement, particularly as delivery of the field-component of the project was hampered by multiple constraints including travel restrictions as a result of the COVID 19 pandemic, destroyed infrastructure on Santo as a result of cyclone Harold and DoF staffing issues. So that momentum is not lost on domestication of canarium, sandalwood and whitewood, putting at risk losing the substantial resources in progeny trials and seed orchards established by this and earlier projects, it is strongly recommended that ACIAR consider funding a follow-on project.

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## 9.2. Recommendations

Future needs in forest research in Vanuatu, as defined by DoF and the project team, are:

**1. Review of DoF research agenda:** Support is needed for a systematic review of DoF's research agenda to set priorities for research and establish resource needs in terms of infrastructure, staffing and financial inputs. This review is paramount in order to assess how DoF research can optimise their contribution to an expanding and enhanced sustainable forestry sector.

**2. Support for research staff and provision of capacity building:** Project implementation has been affected by continuity and availability of staff within the research and extension sections; this also encompassed issues with technical capacity. Ideally, a research team will require: (1) a research manager with existing skills in biometrics (or capacity to be trained in these skills) to lead the research programs; (2) technical support to assist in such activities as seed collection, raising plants, lay-out of experiments, measuring and analysing trials; and (3) outdoor research workers to maintain and assist in measuring trials and other field work as required. There is a need for a systematic

approach to staff capacity building and succession planning to ensure sufficient continuity of expertise to maintain research priorities.

**3. Support for improved smallholder engagement.** Any new investments into forestry research in Vanuatu should consider further adaptation and deployment of extension, through mechanisms such as the Master TreeGrower Program. This is an important avenue for improving gender equity in accessing planted forestry innovations. The DoF does require additional supports to reach a wider array of existing and potential growers. The capacity of the peer-based initiatives in reaching these stakeholders depends on closer support of and cooperation with a hierarchy of organised grower groups. The continued development of training materials in Bislama including promotional media such as the 'Gudfala Tri Blong Mi' video series and more technical methods videos is a very efficient way of increasing the reach of DoF extension resources.

**4. Support for implementing the domestication of the three priority species.** It is recommended to address key knowledge gaps as outlined in the domestication strategies, implement their initial stages and continue deployment of improved materials to support plantation expansion. This will require a continuing commitment of DoF and the private sector to provide on-going physical, human and financial resources to their implementation — Physical resources: land for progeny tests, seed orchards, breeding arboreta; nurseries for the secure raising of source-identified and often valuable (irreplaceable) seed lots, and cuttings; office and computers for the long-term storage of complex and accurate records, reports and analysis of data; store/laboratory for the secure storage of equipment, chemicals, seed and for processing of samples. Human resources: a core of permanent, experienced people need to be developed and maintained in order to give projects continuity. Funding: an adequate and recurrent budget is essential to maintain continuity for the long-term nature of the work.

Domestication will depend on the maintenance and extension of existing genetic resources. For *Canarium* the newly planted provenance-progeny trial needs to be maintained so captures the site and becomes a resource for future selection. Tagabe clone bank is in need of on-site replication (before additional clones are lost) and renovation (wider spacing & establishment of hosts) to increase production of scions and seed for deployment. For whitewood the SSO1 at IFP is in urgent need of maintenance including control of merremia incursion and woody weeds that threaten the health and survival of selected trees. Given that the *Bombua* progeny trial is being used by DoF for whitewood seed collections it is important that it is thinned to the best performing trees so that it functions as an SSO2. Implementing cloning of plus trees and research for controlled pollination and establishment of an SSO3 would accelerate gains already made.

**5. Support for commercial development of the three priority species.** Addressing key needs for each of the industries is important to amplify the impact of the research. It is clear that improved efficiencies in harvesting, primary- and secondary-processing are required to promote attractive financial returns along the value chain. For sandalwood there is a need for sustainable market development. With the peak body to represent the Vanuatu sandalwood industry (VISA) dissolving in 2019 and planted resources beginning to mature, there is a need to undertake research to broaden market access and improve smallholder returns. This requires characterisation of the planted resource, including information about age class, distribution, productivity and heartwood qualities. This is critically important for forecasting annual wood flows and harvesting regimes, developing product specifications and planning the value adding infrastructure required to optimise returns from this resource. Research is needed to address issues related to value chain optimisation, particularly in light of limited international buyers. For whitewood the TRF remains a critical piece of infrastructure to investigate sawing and treatment approaches

suitable for small diameter plantation trees, that make it competitive with imported pine products.

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## 10.2. List of publications produced by project

### 10.2.1. Published

#### *Journal Articles*

- Carias D, Page T, Smith H, Race D, Keenan RJ, Palmer G, Baynes J. 2022b. Beyond the 'Field of Dreams' model in smallholder forestry: Building viable timber value chains for smallholder tree growers in developing countries. *Land Use Policy*. 120:106227.
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#### *Books & Book Chapters*

- Addinsall C, Rihai N, Nasse A. 2019. Agroecology and Sustainable Livelihoods as a Framework to Empower Rural Ni Vanuatu Women. In: Singh-Peterson L, Carnegie M, editors. *Integrating Gender in Agricultural Development: Learnings from South Pacific Contexts*. Emerald Publishing Limited; p. 105-120.
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#### *Conference Papers*

- Bome G, Kalsakau T. 2021. Building Links between Science, Government and Industry for Sandalwood Conservation and Development in Vanuatu. In: Page T, Meadows J, Kalsakau T, editors. *Sandalwood Regional Forum: Proceedings of a regional meeting held in Port Vila, Vanuatu 11–13 November 2019*. ACIAR Proceedings, No. 150. Canberra: Australian Centre for International Agricultural Research (ACIAR); p. 2–4.
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Carias D, Ota L, Page T, Herbohn J. 2022a. Challenges and opportunities for inclusive value chains of forest products in Small Island Developing States: *Canarium* nuts, sandalwood and whitewood in Vanuatu. Report for FST2016-154 Enhancing returns from high-value agroforestry species in Vanuatu University of the Sunshine Coast.

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