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1 Acknowledgments

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[1] *RAIL is a subsidiary of NBPOL, which is in turn a subsidiary of Sime Darby Plantation.*

deliver the benefits to which they and we both aspire, for their and other communities in PNG.

We would also like to thank Ramu Agri Industries Ltd (RAIL) for logistical support and assistance during the Project.

1.1 Acronyms

CLUA	Clan Land Usage Agreement
DCF	Discounted Cash Flow
FA Goroka	PNG Forest Authority, Eastern Highlands Office, Goroka
FORCERT	Forests for Certain: Forests for Life
FPCD	Foundation for People and Community Development
FRI	PNG Forest Authority, Forest Research Institute, Lae
FRO	Forest Resource Owner
ILG	Incorporated Land Group
IRECDP	Islands Region Environment and Community Development Programme
MTDP	PNG Medium Term Development Plan
NBPOL	New Britain Palm Oil Limited
NGO	Non-government organisation
PHF	Pacific Heritage Foundation
PIP	Pacific Islands Program Papua New Guinea
PNGFA	Papua New Guinea Forest Authority,
RAIL	Ramu Agri Industries Ltd
RMV	Ramu/Markham Valley
SGS	*Sociele Generale de Surveillance*
TA	Timber Authority
TFTC	Timber and Forestry Training Centre, Lae, Papua New Guinea
UPNG	University of Papua New Guinea
USC	University of the Sunshine Coast
VDT	Village Development Trust

2 Executive summary

The purpose of this project was to identify how community forestry in Papua New Guinea (PNG) could be better enabled and how it might be scaled up to achieve better economic, social and environmental outcomes. The research focused on three main objectives; two on reforestation and the third on small holder natural forests as follows; (1). designing and testing novel tree-based livelihood systems for family-focused community-based reforestation; 2) methods by which family-focused community-based reforestation can be scaled-out to a landscape scale; 3) identifying and pilot testing institutional arrangements and policy recommendations which improve access to formal timber markets by smallholders. Objectives 1 and 2, were aimed at family- based reforestation activities including agroforestry which could be scaled up across communities and the landscape. The research methods involved a combination of improving technology through training and extension activities which were also a means of collaborating with communities which also facilitated social-science and biophysical data collection. This collaborative approach with all stakeholders increased the understanding of the policy and institutional systems facilitated through meetings, conversations and visual observations.

Work in the Ramu-Markham Valley (RMV) was undertaken in partnership with Ramu Agri Industries Ltd (RAIL). Through action research a process was developed in which agreements were made with clans to experiment with training selected farmers to establish and manage small nurseries to provide planting material for individual farmers to plant trees on their family plots. Although the original concept was to identify species desired by farmers, this was revised as requested species were not always available or suitable. Instead, the focus was on what outcomes/ services (food, timber, fuelwood, shading for crops etc) people (women and men) wanted from planted trees. The trees selected for planting were based on these preferences and on available and suitable tree species. The research showed that people adapted what they learned through project training by experimenting with nursery techniques and mixes of tree species that differed from any standard packages. Importantly, the process of testing these “novel livelihood systems” required considerable negotiation with and between community members and was far more about experimentation and adaptation than adoption of existing models.

An agroforestry demonstration plot was established at Umi in an accessible location so passers-by or invited groups of villagers could observe a variety of plots with different mixes of trees and food crops. This demonstrated a variety of agroforestry options which farmers could then adopt and adapt. Two agroforestry demonstration plots were also established with individual landowners near Goroka in the Eastern Highlands. Based on the data from the Umi plots, bio-economic models of the various agroforestry options were developed to compare the estimated financial returns to farmers.

Objective 3 was aimed at identifying institutional arrangements and policy reform that would allow communities better access to formal value-added timber markets. The research involved a combination of a literature review with thematic analysis of past small-scale forestry operations, a discounted cash flow (DCF) analysis of portable sawmill operations, a cash flow analysis of PNG log export revenue distributions to forest resource owners (FROs) over approximately three decades, and a descriptive case study of the Timber Authority (TA) regulations and the small-scale forestry informal market. We identified several policy reform options to allow communities better access to formal value-added timber markets.

Spacing trials and mixed tree species were established at Goroka, RMV and near Lae. The longer-term scientific impact of the species trials will be significant; the species trials in the RMV & Lae will contribute to an understanding of the most socially and ecologically appropriate species for reforesting grasslands along with knowledge of species interactions in mixed species stands and optimal spacings of different species in grassland reforestation.

3 Background

The forests of Papua New Guinea (PNG) are estimated to cover between 29 and 33 million hectares (FRA 2015) or sixty-three percent of the country's 46 million hectares (PNGFA 2012). Plantations are estimated to cover between 62,000 and 86,000 hectares (FAO 2016, PNGFA 2012), with many being of low stocking and poor quality. About eighty percent of the population of PNG live in rural areas and they depend heavily on their forests for fuelwood, housing timbers, a variety of non-wood forest products, and in some areas depend on forests for swidden agriculture. Community forestry offers a mechanism for improving rural livelihoods in PNG. Women play a key role in obtaining and managing household resources in PNG (Allen 2009). They are thus integral to successful community forestry, especially in relation to agriculture and tree-based land use

The PNG Medium Term Development Plan (MTDP, 2015) emphasises that the "forestry sector continues to contribute immensely to the national economy, as well as "improving the livelihoods of the rural poor" and sets a goal to "build a forestry sector that is sustainable and highly profitable." The importance of community forestry in achieving this goal is explicitly recognised through one of the nine sector strategies, namely to "Promote community forestry activities with the view of empowering rural communities and alleviating poverty." Plantation forestry is also recognised as being important to "Develop forest plantations to meet the impact of climate change and to meet future timber demand for both domestic and international markets". To facilitate the expansion of the plantation estate, the PNGFA continues to promote a program called '*Painim Graun, Plannim Diwai*' (Search for land and plant trees) which plans to expand the plantation estate in each Province by at least 1000 ha per annum.

The PNGFA places importance on community forestry but is aware of the impediments preventing its uptake in PNG, as confirmed by the previous ACIAR Project FST/2011/057 'Enhancing the implementation of community forestry approaches in Papua New Guinea'. While community-based forestry is now being widely practiced in developing countries, its success is influenced by a complex range of factors. In a meta-analysis of the literature undertaken as part of FST/2011/057, Baynes et al. (2015) have identified five key factors that influence the success of community forestry groups namely: the importance of effective governance; secure property rights; social equity; government support; and tangible benefits.

Analysis of the social dynamics underlying decision-making about forests was undertaken by Fisher (2017) as part of the work of FST/2011/057, which preceded and informed the current project. He identified several important themes:

- confirmation of the common reluctance to cooperate above the clan level;
- common inter-clan and intra-clan conflict especially over land;
- the tendency for both agroforestry and reforestation activities to be carried out by small sub-groups within a clan, often consisting of a few close kin."

Fisher (2017) pointed out that clans do not act collectively for economic activities. Clans allocate land to clan members who make decisions about land use on their allocated land. The process of decision-making about land use by clans and individuals remained a priority for further research in the current project, especially in the context of a new focus on agroforestry activities. This topic was a particular priority in this project as the role of women in decision-making became crucial.

Legislation introducing Incorporated Land Groups (ILGs) was developed as a way of assisting traditional owners to establish a form of legal structure to facilitate financial arrangements associated with forestry and mining royalties and "to promote business and cash-earning opportunities in rural Papua New Guinea" (Weiner 2013). Some difficulties with the practical working of ILGs have been identified (e.g. Weiner 2013), including concerns that they have not been able to deal with the scale of resource management and development issues that have emerged. As a means of negotiating land use within clan owned lands, there have been experiments with Clan Land Usage Agreements (CLUAs) for application to cash crop production (Koczberski et al. 2013). Although CLUAs have been used at RAIL, it has not been applied widely to forestry. However, there is some potential for application in agroforestry operations and especially for empowering women who traditionally do not have clear land rights.

Another challenge for the project was the need to achieve an appropriate degree of aggregation of tree planting and timber resource availability to facilitate market interest for the forest products from community forests. These issues are complex, especially in relation to the intra-community forestry collaboration, socio-economic, gender equity and property rights, such as land ownership by clans. Therefore, community forestry interventions need to look at both clan and individual or family behaviours and the interactions between them. The resulting processes of negotiation require detailed and patient research.

The project's planning recognised that new research was needed into the conditions necessary for community-based (multi-species, multi-purpose, livelihood-based) plantings on deforested and degraded land. The new research needed to include social science research, looking particularly at social dynamics related to land use decision-making, biophysical research related to species selection, technical research related to processing and research into policy options for enabling community forestry.

There was confirmation from the PNG stakeholders that the priorities for a new project should be focused on improving the implementation of community-based reforestation and agroforestry of grasslands. There were (and still are) large areas of clan owned grasslands covering thousands of hectares where clans are seeking opportunities to use more productively. Community-based reforestation or agroforestry in these areas has great potential where some initiatives have commenced to address the issue (Global Environment Outreach Centre in the Eastern Highlands; ITTO high value teak plantings in the savannah grasslands and Papua New Guinea Forest Authority's (PNGFA) promotion of the nitrogen fixing *Casuarina oligodon*) but have had minimum impact due to a number of impediments. These include; invasive fires, seedling availability and quality issues, lack of technical knowledge, availability and affordability of suitable seed sources, and markets. Additional research is required, particularly in developing knowledge to best support the development of women in rural environment and how women working with men in a family unit can lead to improved agroforestry systems and profitable livelihoods (Pamphilon and Mikhailovich 2016, Mikhailovich et al. 2016*).*

In 2016, harvesting natural forest was estimated to produce over 4.4 million cu m of timber annually, with 4 million cu m exported in log form (SGS 2016) and almost all coming from clan forested lands. However, there is a growing recognition of the importance of clan-based community forestry operations using portable sawmills, which were estimated to number 1,500 (Grigoriou 2011) in unlogged natural forest, as well as logged-native forest (recovering from previous logging) (Wilkensen 2013). New research was needed into the conditions necessary for community-based sustainable management, harvesting and log processing of native forests.

In planning the project there was also considerable support from clans that a new project should also focus on improving the implementation and community eco-forestry (small holder harvesting and processing) outcomes for clans and to improve returns to the smallholders involved in natural forest management. PNGFA shares these priorities to help meet the current policies to reduce poverty of the rural poor as stated in the Medium-Term

Development Plan. Eco-forestry has been advocated by a number of NGOs and community groups (Bun and Baput 2006, Rogers 2010), and has been supported by the PNGFA. Although the PNGFA has continued to express support for eco-forestry, the existing forest and legislative policy framework imposes complex, technically challenging and expensive requirements for landowners to harvest timber for commercial use. In particular, communities are required to obtain a Timber Authority (TA) which is costly and has requirements which many communities have difficulty in meeting, including the requirement for a 20,000kina (approximately AUD8,200) bond. Without a Timber Agreement, communities cannot legally sell clan timber, although many still harvest timber illegally and sell into lower value informal markets.

The current concept of eco-forestry within PNG is restricted to small-scale sawmilling to produce rough-sawn lumber. The focus of donor support to date for eco-forestry has been through support for the purchase of small-scale portable sawmills and associated marketing units (sometimes referred to as Central Marketing Units - CMUs) for the timber produced through milling of clan timber. An analysis conducted as part of FST/2011/057 indicated that CMUs, as currently practiced, have been established in PNG by eco-forestry focused NGOs, including the Foundation for People and Community Development (FPCD), the Village Development Trust (VDT), the Islands Region Environment and Community Development Programme (IRECDP), the Pacific Heritage Foundation, and FORCERT along with 50+ eco-forestry sawmills. None currently appear to be operating after donor support was withdrawn.

In summary, the project intended to address the following issues:

- The contribution of community forestry to the national economy especially related to the livelihoods of the rural poor;
- Understanding the social dynamics underlying decision-making about forests and reforestation, focusing especially on understanding clan and individual roles;
- Exploring the conditions related to community-based planting of deforested and degraded lands;
- Improving the implementation of community-based reforestation and agroforestry on grasslands;
- Developing knowledge to support women’s development and role in improved agroforestry systems and improved livelihoods;
- Addressing policy issues related to eco-forestry.

Applying this knowledge along with improved technology and training through improved extension to produce urgently needed products, while producing positive social and environmental outcomes was identified as a way to improve livelihood options and reduce poverty in rural communities.

4 Objectives

Most of the land in PNG, including both land with forests and land which is now deforested and dominated by grasslands and largely 'open access' in terms of active management for sustainable uses, is owned by clans under customary tenure recognised in the Constitution. The project was developed with three main objectives: two focusing on a family-based approach for implementing tree-based livelihood systems for reforestation and a third on improving returns to smallholders involved in natural forest harvesting and processing.

The aim of the Project is to improve rural livelihoods through family-focused community reforestation and small-scale harvesting and processing in PNG. The three main research objectives and associated activities are as follows:

Objective 1: Design and test novel tree-based livelihood systems for family-focused community-based reforestation

Activity 1.1 Identify community preferences for family-based reforestation.

Activity 1.2 Develop bio-economic models for tree-based livelihood systems

Activity 1.3 Establish field trials which address key areas of technical deficiency

Activity 1.4 Pilot test most promising tree-based livelihood systems with families.

Activity 1.5 Improve quality of multi-species mixed native forest reforestation on HCV areas

Activity 1.6 Establish and maintenance and measurement of species /spacing trials

Objective 2: Identify the methods by which family-focused community-based reforestation can be scaled-out to a landscape scale

Activity 2.1 Assess community-based reforestation initiatives in the Asia-Pacific

Activity 2.2 How to enable landscape-scale reforestation

Activity 2.3 Implement reforestation in the Ramu-Markham Valley and Eastern Highlands

Activity 2.4 Develop extension materials and best practice guidelines

Activity 2.5 Design and implement a monitoring program for community forestry initiatives

Objective 3: Identify and pilot test institutional arrangements and policy recommendations which improve access to formal timber markets

Activity 3.1 Identify key constraints associated with the current Timber Agreement for clans

Activity 3.2 Identify possible ways to improve the Timber Agreement for smallholders

Activity 3.3 Develop Reduced Impact Logging (RIL) guidelines for smallholders

Activity 3.4 Undertake demonstration of RIL and Management Plans for clans

Activity 3.5 Improved management of the eco-forestry/smallholder systems

Activity 3.6 Identify alternative marketing models and develop financial programming

Activity 3.7 Explore value adding opportunities for community timber in local sawmills

Objective 1: The activities involve developing an understanding of community preferences for tree species to assist in the development of models for tree-based livelihoods. The models will be supported by family-based field trials and PNG Forestry Research Institute (PNG FRI) species trials, testing promising tree based multi species systems for both livelihoods and conservation. The outputs include the identification of preferred species by communities and results from testing these species in different planting designs.

Objective 2: This objective aims to facilitate an expansion of clans involved in family focused community forestry. The research activities will explore current inter and intra clan decision making processes, and then test amended approaches in a few communities to enable an increase in reforestation on clan land. The outputs will include a) a report on social dynamics related to decision making in forestry, b) best practice guidelines and training manuals, as well as c) a monitoring framework for community focused forestry initiatives which will be used to inform PNG national reforestation policy.

Objective 3: Activities in this objective involve reviewing the established institutional arrangements, regulations and procedures for smallholder forestry in PNG, and proposing amendments to improve the access of community-sourced timber to formal value-added timber markets. Research activities will include a) an analysis of the Timber Authority process and its suitability for small-holder participation in formal timber markets and to inform proposed amendments, b) the development, demonstration and promotion of a revised Reduced Impact Logging (RIL) or an improved harvesting system for smallholder harvesting operations by PNGFA staff and smallholders. The outputs will include a) with the assistance of PNGFA, a proposed improved management system for smallholders to input into the national policy, as well as b) producing alternative marketing and financial models, along with training and to evaluate financial performance of harvesting and marketing operations for small scale, clan-based operators in PNG.

5 Methodology

The project design was guided by our previous experience in community-based forestry research, which necessarily depended on a multi-and inter-disciplinary approach, involving social science field methodologies and biophysical research. It was also dependent on developing strong partnerships between researchers at USC and research partners and their organisations in PNG. The research partners in PNG involved in each of the objectives and activities are outlined below.

The project operated in the Ramu-Markham Valley (RMV), Eastern Highlands/Goroka and Lae Regions, i.e. in the communities living in the grassland dominated areas in the vicinity of Ramu Agri Industries Limited (RAIL) estate, communities living in the Eastern Highlands, adjacent to the town of Goroka, areas adjacent to the north of Lae at Setun managed by the Forest Research Institute in Lae and the area near Oomsis where the Timber and Forest Training Centre (TFTC), Unitech) has ongoing research with local landowners, located nearby the Bulolo to Lae Road as shown in Figure 1.

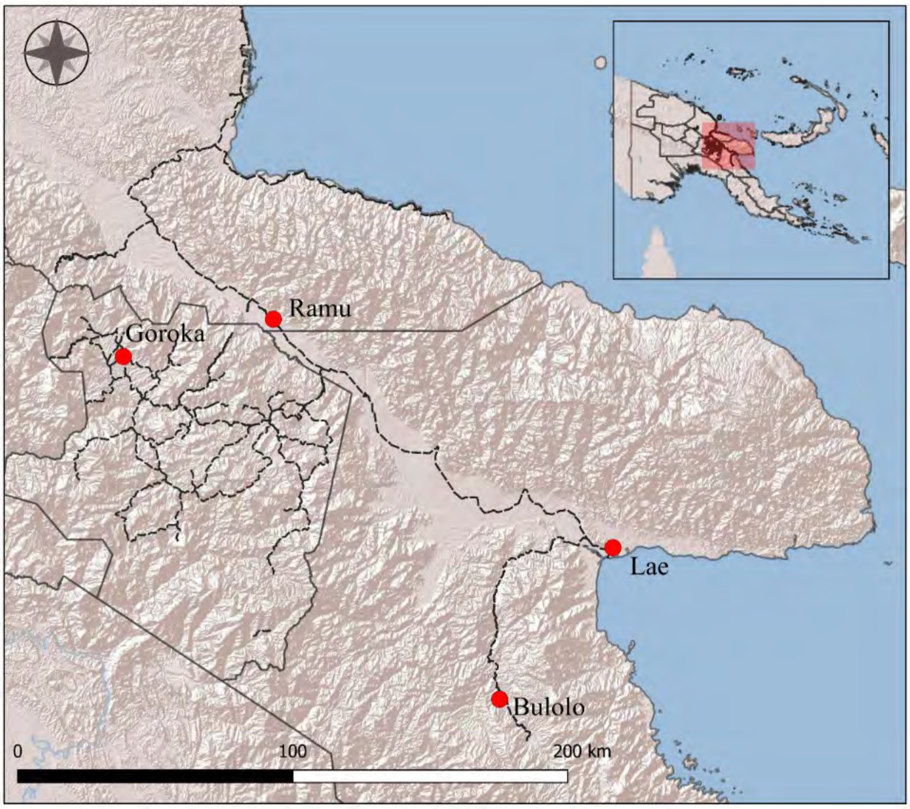

Figure 1: Location of Project sites in Ramu-Markham Valley, Goroka and Lae in Papua New Guinea

As the lead agency for forest research in PNG, the Forest Research Institute became the lead partner for the project,[2] with their research focused on the species trials and mixed species reforestation trials in the vicinity of Setun.

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[2] The Forest Research Institute is a department within the Papua New Guinea Forest Authority (PNGFA) and operates with its own budget in this Project.

RMV refers to the area around RAIL at Ramu. The Ramu Valley is part of Madang Province, while the Markham Valley is in Morobe Province.

The RMV was chosen because its extensive grasslands are well suited to research on community-based reforestation/ afforestation and agroforestry. Ramu Agri Industries Ltd (RAIL) is a large private agricultural company, located in the township of Ramu in the RMV. RAIL has a demonstrated internationally recognised track record in reforestation for its High Conservation Value Forest Program and community development and provided a research partner already engaged with communities involved in reforestation. RAIL was a partner in previous ACIAR projects.

The Eastern Highlands Province, of which the capital is Goroka, was also chosen due to extensive areas of elevated grasslands and for its ongoing species trials and community reforestation and agroforestry demonstration activities. The area has similar social conditions and biophysical characteristics (extensive grasslands) to the lowlands in the RMV, except these are at a higher altitude with different climatic and edaphic conditions. The PNGFA also has staff involved in community reforestation and has a regional office in Goroka. Hence both the PNGFA in Goroka and RAIL staff were involved in undertaking many of the activities in Objective 1 and Objective 2.

The areas around Lae were selected as a location suitable for research into smallholder forestry because of the high concentration of native forests there and the fact that the Timber & Forestry Training Centre, (TFTC) has on-going research activities with landowners in close proximity. This area thus provided a suitable location to undertake the planned activities involved in Objective 3.

The Forest Research Institute (FRI) is also located in Lae and has areas to the north of Lae at Setun, where they have other trials, thus making it a suitable partner for undertaking species trials associated with Objective 1. The FRI research area at Leron was initially chosen, but the community areas in and nearby Setun were found to be more suitable and were finally selected[3]. Hence, the TFTC and FRI were involved in facilitating community involvement in and collaboration with these communities to undertake a number of the activities in Objective 1 and Objective 3.

Many of the activities, including the biophysical research involving species field trials and community-based reforestation and agroforestry research included social science research field methods, group interviews, semi-structured interviews, and participant observations. The underlying methodology here involved participant observation, which involved careful observation of interactions with and between community members, combined with interviews and discussions on their needs and their reasons for making land use decisions. The participant observation was combined with field-based community meetings by the PNG project staff. Observing interactions at meetings (sometimes referred to as "event ethnography") and observing how and whether decisions are implemented and if not, why not, is a crucial way to understand decision-making processes and to inform negotiations over land use. It is essential to recognise that both research about and negotiations over land use required extended discussions with actors and was not completed in a couple of visits and large meetings. Participant observation also involved "walk-around" discussions with various stakeholders to obtain a clear understanding of their positions before formal negotiations began as outlined in Fisher (2017).

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[3] *FRI has numerous trials at Setun including other ACIAR tree improvement trials.*

5.1 Methods specific to each project objective

The methods developed and the researchers involved in the activities, the locations, and the specific sites where the work was undertaken within each objective are described along with a broad description of how the research was undertaken is provided in this section.
The main component of the social science research was guided by Robert Fisher (anthropologist), who led the RMV work, in collaboration with Ms Melinda Thom and Nathan Wampe from RAIL and Jack Baynes from USC. Ms Vincianna Andrew from PNGFA in Goroka undertook the community-based activities in Goroka as a social science field researcher in collaboration with Robert Fisher. In 2018, USC PhD candidate Ms Kanchana Wiset also became involved in the social science research in the RMV. Micah Scudder undertook the financial analysis of the agroforestry research and assisted with the monitoring systems for the family-based reforestation activities with Nathan Wampe from 2019.

The species and variable spacing trials were designed by Dr David Lamb and Dr Jerry Vanclay. They also provided similar designs for ACIAR funded Projects in previous PNG Projects (FST /2011/057) and in the Philippines (ASEM 2010 /050), so results across sites and species could be readily compared. These trials were implemented at RAIL by Zephaniah Waviki and Nathan Wampe and by Ms June Mandawali, Haydrian Morte and Gedisa Jeffrey from FRI at Setun and by Mr Warea Andasua, assisted by Haydrian Morte and Anton Lata at Goroka.

Preliminary field work and a desk review of partnerships with several villages led to the selection of Marawasa, and Atzunas for project interventions. Bopirumpun was added subsequently in place of Marawasa and Umi was added (as a demonstration site for agroforestry trials). Intervention in each of these sites was negotiated with clans and local families. Social science field research commenced at Atzumas and Marawasa in late March 2018 following Social Science Research Training by Robert Fisher for research partners involved in the community-based forestry and agroforestry components of the Project.

Micah Scudder, Charles Tsiritsi (TFTC), Claude Saliau (PNGFA) and Grahame Applegate were involved in the research to promote greater value for small holders or resource owners involves in natural forest harvesting and processing. This research was undertaken in Oomsis and Lae.

Micah Scudder, Grahame Applegate and Jerry Vanclay were also involved in developing and presenting training to partners on publication enhancement (in association with Dr Laura Graham FST /2016/144 Indonesia), forest species trial design and layout, forestry finance and variable spacing and mixed species trial design and data analysis.

5.1.1 Objective 1: Design and test novel tree-based livelihood systems for family-focused community-based reforestation

Activity 1.1 Identify community preferences and site conditions for family-based reforestation.

The Social Science Research Training Workshop was undertaken by Robert Fisher from 22-26 January 2018 at RAIL with 12 participants from USC, RAIL, the PNGFA, and FRI as a preliminary activity for the social science research. This training was required to assist all researchers involved in all three objectives, as each had social science research activities. The Workshop trained participants in social science research methods relevant to the project, with a focus on qualitative methods and an emphasis on interviewing techniques and skills. This included classroom practice exercises and a field practice exercise.

In the initial stages of the Project, up to March 2018, staff turnover in the Project was substantial, and a great deal of time was involved in recruiting for the new staff positions. These staffing changes were mainly at RAIL and FRI.

The activity also involved qualitative social science research (including interviews, participant observation and case studies), especially related to gender roles and gender concerns and was designed to identify community preferences disaggregated by gender. This research aimed to identify potential cash crops that could include tree species, coffee, cocoa, fruit trees, pandanus nuts, *taun, galip, okari (Kaernbachii* and Catappa) as part of home garden enterprises. However, the idea of identifying preferred tree species was abandoned in favour of identifying the "services and benefits people wanted to obtain from farm-based agroforestry". The rationale for this change is that a narrow focus on people's preferred tree species could lead to identifying inappropriate or unavailable species. This improved concept replaced what was previously described in Activity 1.1 as the species preference study and was subsequently followed as part of the community case studies.

A preliminary market analysis was undertaken as part of the process of identifying suitable tree species and potential cash crops. This work drew on research from past ACIAR projects (e.g., FST/2006/050, FST/2011/058, facilitating the establishment of charcoal producer groups in Papua New Guinea and FST/2011/057 which identified charcoal, bioenergy and firewood as potential markets).

Activity 1.2 Develop bio-economic models for tree-based livelihood systems

Data for the model in this activity utilized a mixed-methods approach. Growth and yield data for the specific agroforestry crops was collected from the peer-reviewed literature, final reports from previous research projects in PNG conducted by ACIAR, and other published reports. Site specific data for the RMV was collected via interviews by Claude Saliau (PNGFA), Micah Scudder (USC) and Nathan Wampe from RAIL using a combination of interviews with community members, information from the literature and expert opinion from the CCI, PNGFA staff and cocoa marketing companies operating in the RMV. Discounted cash flow (DCF) models were developed in Microsoft Excel Software to evaluate the financial viability of a variety of tree-based livelihood systems. The tree-based livelihood systems that appeared to be most favourable from the perspective of financial viability were inserted into a linear programming model to identify the optional system mix given specific constraints to available labour and land area.

Activity 1.3 Establish field trials which address key areas of technical deficiency

A network of field trials at suitable sites across the Ramu-Markham Valleys and Eastern Highlands was established based on common designs for and variable spacing trials (Lamb et al.1998; Vanclay 2006) The field trials were designed to address knowledge gaps in technical information (e.g.. optimum spacing of tree species, reducing the impacts of fire, tree species and suitability and their suitability for various cropping systems). The field trials were established by PNGFA and by RAIL staff who undertook training in design and layout in preparation for the research trial plantings. A variable spacing trial with 4 species was established in 2020 on RAIL land by RAIL staff in collaboration with USC researchers. A variable spacing trial involving four species was established in Kintinu near Goroka by PNGFA. Commencement Reports were prepared in conjunction with research partners for the on-going field trials.

During the early stages of the Project, it became apparent that many of the researcher partners from ACIAR Projects managed by TFAP in the Philippines and in PNG who were involved in both the social science research and the more technical aspects of reforestation research and undertaking species, spacing and mixed species field trials, had limited capacity to undertake their research effectively. Consequently, to assist in developing their capacity to undertake research, we developed and presented a 3-day training session with over 36 participants, involving 10 females and 26 males from 11 institutions from PNG and the Philippines in a Workshop at Visayas State University in Leyte (main partner of the ASEM 2016-103 project), following the Forest and Landscape Restoration International Conference in Manila. The training was jointly organised by this project FST 2016/ 153 and ASEM 2016-103.

Activity 1.4 Pilot test most promising tree-based livelihood systems with families

The researchers from RAIL and USC selected the villages of Marawasa and Atzunas in RMV and identified families interested in participating in trials and preparing them for negotiations with clans to undertake the trials. These community focused trials with tree-based livelihood systems were planned to involve four to six families per region (8 – 12 participatory trials in total). The systems investigated included a *Eucalyptus pellita*/coffee/cocoa system along with others identified in Activities 1.1 and 1.2. Activity 1.2 was undertaken later than planned due to staff changes. Activity 1.1 was also modified to focus less on species preferences and more in what benefits communities wanted rather than what tree species they were seeking. In contrast to Activity 1.3, the livelihood systems were implemented in conjunction with families, who were also be involved in the selection of species and agricultural crops. Action research and participant observation were the primary methods to implement the trials and monitor species development and community impacts. Multi-species, multi-purpose agroforestry tree-based livelihood demonstration plots were established at Umi (RMV) by RAIL staff and the landowner and at Marasin and at Ifiufa (0.16 ha each) in Goroka in the Eastern Highlands by PNGFA staff from Goroka and local landowners. The demonstration plots included agroforestry systems involving a range of tree species and spacings along with a range of cash crops and livelihood systems under farmers' conditions.

Activity 1.5 Improve quality of multi-species mixed native forest reforestation on sites of high conservation value

The initial activity was designed to undertake an assessment of the diversity of tree species in the RAI nursery and to include the current nursery design and production capacity. The purpose was to identify challenges in the nursery operation and how prepared it was to provide an optimal mix of species for timber and non-timber products for the RMV plantings and HCV plantings required by RAIL.

The second set of activities involved the design, establishment, and evaluation of two field trials on different sites involving mixtures of native tree species. The key focus was to identify key species to include in the planting mixtures, improving access to germplasm, improving survival rates, identifying the most effective planting designs and early-age silviculture. The design of the field trial built upon the promising results from a limited number of field trials established in FST/2011/057 and from literature related to mixed-species reforestation including using functional trait analysis to select species for inclusion in mixture plantings. Monitoring and reporting were planned to include information on species configuration, species used, and progress information on growth and mortality.

A field trial involving a mixture of 16 species were established in 2019 at Ramu by RAIL staff in collaboration with USC staff. In addition, the 'high species diversity' nursery at Ramu was in need of an upgrade with increased technical input to demonstrate appropriate nursery techniques and to source and propagate germplasm for mixed-species reforestation. It will also provide germplasm for the field trials program.

A mixed species trial involving the same four species as the spacing trial was established in Matox near Goroka by PNG-FA staff with assistance from FRI staff from Lae.

Activity 1.6 Maintenance and measurement of species trial established by FRI at Leron in FST/2011/057 and extend trial with additional species

The trial that was planned in FST /2011/057 at Leron did not take place, so FRI implemented the trial in 2017 as part of FST /2016/153 using funds from FRI. The site for the species trial was moved to Setun (near Lae) as a variable spacing trial established by FRI staff (Haydrian Morte, Anton Lata, June Mandawali). The trial design involved 4 species (*Anisoptera* sp., *Alstonia scholaris*, *Falcataria moluccana* and *Eucalyptus pellita*, using the variable spacing design used on the other sites in the Project. A mixed species trial under FST/ 2016/153 (planned for 2017/8) was established in April 2022, involving 4 tree species. Both trials were to be maintained and protected from fire and will have initial and then periodic measurements for tree height, diameter and mortality. The initial results were planned to be analysed and presented in a Workshop towards the end of the Project in September 2022 when some initial results were to become available.

5.2 Objective 2: Identify the methods by which family-focused community-based reforestation can be scaled-out to a landscape scale

Activity 2.1 Assess community-based landscape-scale reforestation initiatives in the Asia-Pacific to identify key factors likely to impact success for scaling out

A review of existing tree-based livelihood initiatives in the Asia-Pacific region was designed to identify promising strategies and integrate results to prepare an influence diagram outlining linkages between key drivers of success. This was undertaken by Jack Baynes, Kanchana Wiset and Grahame Applegate and drew on resources and knowledge from community-based reforestation in the Asia Pacific region.

This activity also involved an International FLR Conference which was held Manila in February 2019, organised by USC (projects ASEM/2016/103 and FST/ 2016/153) in collaboration with Visayas State University in the Philippines. A number of papers were presented by the USC and PNG partners.

Activity 2.2 Explore how to build cooperation within and between families and clans to enable landscape-scale reforestation

The research was largely undertaken at Ramu by RAIL project staff, in consultation and under the guidance of Robert Fisher along with USC PhD student Kanchana Wiset. The research involved group interviews, semi-structured interviews, participant observation of meetings and participatory extension activities in villages, some of which were identified in FST/2011/057 in the Ramu-Markham Valley and around Goroka. To enlist villagers' cooperation and their motivation to participate, social-science research was carried out in conjunction with field trials involving vegetables, cash crops and trees, i.e. livelihood based tree and crop combinations which could motivate villagers to experiment and apply the results to their own changing circumstances.

The experiences gained in family-based reforestation in the Sangkian community in the Ramu Valley during FST/2011/057 was used for developing an improved model as well as drawing on lessons from other initial research results from Activity 2.1. The research also included possible ways to reduce the occurrence of anthropogenic fire through social initiatives and modified reforestation designs. The methodology adopted changed as Activity 2.1 was delayed and the extended, (but not unexpected) due to the long but essential consultation process with communities.

The research outputs were planned to include guidelines and testing of a process through meetings and discussions for facilitating and supporting negotiations and conflict management between clans and between clans and individual clan members which would facilitate landscape-scale reforestation. This research was intended to be ongoing for the duration of the project to support effective implementation of planned community-based activities and to understand community perspectives and responses to these activities. The most critical aspect of this activity is the nexus between biophysical activities (e.g. trialling crops) and social-science objectives (e.g. achieving inter-or intra-clan cooperation). A report on agroforestry interventions at Ramu summarized the process and results of Ramu community consultation conducted.

Activity 2.3 Implement pilot reforestation initiatives in partnership with communities and families in the Ramu-Markham Valley and Eastern Highlands
The aim was to develop appropriate designs and implement, in collaboration with communities, landscape-scale, multi-species, multi-purpose, livelihood-based tree plantations with four communities and up to 50 families. The results of Activities 1.4 and 2.1 guided the species and planting configurations in this activity which was staggered over three years. In the Eastern Highlands, the research was carried out in partnership with both the communities and the PNGFA. This work was undertaken by Vincianna Andrew from PNGFA in Goroka. In the Ramu-Markham Valley similar research was undertaken with the communities and RAIL with the work being carried out by Nathan Wampe, Melinda Thom, Zephaniah Wiviki and others. While it was anticipated that the pilot plantings were to be progressively implemented, the aim was to have two pilots established in the first two years and the remaining two pilots established by the end of the third year. The nursery activities and the reforestation activities took longer than planned. Eight families were identified for planting in late 2019 at Atzunas, Marawasa, and Bopirumpun in the RMV and 6 communities were identified in 2020 in the Eastern Highlands in 2020. Family-based tree nurseries were established in Atzunas, Marawasa, and Bopirumpun with more than 6 farmers trained to prepare the seedlings and undertake the plantings.

It is important to note that the implementation of pilot activities in the RMV was delayed, firstly because of delayed transfer of funds. This meant that nurseries were not prepared until too late to provide seedlings for planting during the rainy season. so planting did not commence until the 2018-2019 wet season, a delay of 2 years. A further delaying factor was that the extension process in which communities are contacted and negotiations about activities occur, takes time and preparations for nursery development and training and plantation establishment cannot take place before these activities are carried out. The report “Agroforestry Interventions at Ramu” describes the extension process and argues that developing and testing pilot sites requires a considerable amount of time.

Activity 2.4 Develop extension materials and best practice guidelines
Extension and training materials on community reforestation including materials on seedling production, plantation establishment and management were proposed to provide information about best practices and enhance the capacity of stakeholders in designing, implementing and monitoring community reforestation. The approach involved reviewing existing documents, drawing on relevant approaches from elsewhere in the Pacific and relevant experiences from the implementation of project activities, especially similar community-based reforestation research in the Philippines (ASEM 2016/103). These materials in various forms were completed by September 2022.

Activity 2.5 Design and implement a monitoring program to assess family-focused community forestry initiatives
In collaboration with PNGFA staff and the team at RAIL, a methodology for a long-term monitoring program was developed with assistance from Micah Scudder from USC. The

program was developed to track the impact of community reforestation activities in the landscape and within communities. The monitoring program was implemented across four communities and associated families involved in programs under FST/2011/057 and with the communities in this project. The monitoring program focused on key social, economic and biophysical indicators that are robust and are simple enough to be measured at low cost, and which provide an accurate picture of the impacts of reforestation in watersheds. This monitoring was implemented at RAIL largely by Nathan Wampe and Melinda Thom with large inputs from Micah Scudder. The research was designed to involve PNGFA staff in the implementation in the Eastern Highlands. Due to the delay in reforestation activities in the Eastern Highlands, the implementation of the monitoring program focused on the communities around RAIL for the villages involved in the family-based reforestation activities. The monitoring work was not followed up in RMV with provision of new data following the impact of the COVID pandemic from early 2020 onwards.

5.3 Objective 3: Identify and pilot test institutional arrangements and policy recommendations which improve access to formal timber markets

Activity 3.1 Identify key constraints associated with the current Timber Agreement process for clans to access formal timber markets.

This activity involved action research working with selected communities and small-scale timber producers as well as the PNGFA to identify constraints and improvements for a Timber Authority, to facilitate improved access to formal timber markets for clan-based forestry operations. The research which was largely undertaken by Micah Scudder, Jack Baynes, Claude Saliau, and Grahame Applegate, which involved field-based group interviews, semi-structured interviews, participant observation of meetings long with detailed discussions with PNGFA. The rural forest communities selected for interviews were in the Morobe Province on the outskirts of Lae. Small-scale timber producers were interviewed near the city of Lae, as well as in the neighbouring Madang Province near the city of Madang. We also conducted additional interviews with non-participant stakeholders that had expertise in forestry in PNG. In Lae, we interviewed seven professor/teachers from the Timber and Forestry Training College (TFTC). In Madang, we interviewed four employees of the Foundation for People and Community Development, an eco-forestry focused non-governmental organization (NGO). In Madang, we also interviewed four provincial staff members of the PNGFA. In Port Moresby we interviewed an additional eight PNGFA staff members, a forestry professor from the University of PNG, a conservation and community development NGO representative, and two logging industry representatives. A total of 50 people were interviewed. The research included developing an understanding of the community dynamics, decision-making processes and institutional arrangements in relation to natural forest management, which will be an input into the development of an alternative model to improve value to small-holders.

Activity 3.2 Identify possible ways to improve the Timber Agreement process for eco-forestry

Discussions in collaboration with staff from the PNGFA Policy Directorate, small scale producers and selected communities were undertaken by Micah Scudder, Grahame Applegate and Charles Tsiritsi from TFTC for the review and revision of the Timber Authority requirements, including the required documentation and associated costs for communities involved in small-scall forestry. These activities included; field discussions, semi-structured interviews and meetings. An assessment of what level of costs are appropriate for communities to bear and the role that entrepreneurs can play in helping communities capture the value of their forest resources through access to value-added markets. A report was drafted and discussed with staff from the PNGFA, FRI, and TFTC, that described the results of the analysis in activities 3.1 and 3.2. A Policy Brief which incorporated feedback from the PNGFA, on suggested improvements for smallholders involved in natural forests in relation to the TA process. At the suggestion of PNGFA, this policy brief was combined with the brief produced for Activity 3.6.

Activity 3.3 Develop Reduced Impact Logging (RIL) guidelines for eco-forestry to be included in the Timber Agreement

The aim was to develop revised RIL guidelines appropriate for small- scale operations, that reflect community and PNGFA interests and the desire to achieve environmental sustainability given the local terrain and conditions that exist in PNG. For this activity, it was recognized that timber harvests with RIL are just one component of forest management and represent a single section of typical forest management plans (FMPs). We decided that it would be pertinent to also include guidelines for the development of small-scale FMPs. Micah Scudder undertook a review of the existing FMPs used by eco-forestry NGOs, the PNGFA logging code of practice, and RIL guidelines produced for other tropical countries. In addition, interviews were conducted with FROs and small-scale timber producers. These interviews are the same as those discussed in Activitiy 3.1 and 3.2.

The specific eco-forestry FMP and harvesting activities that were assessed to identify which would beneficial and should be incorporated in the future, and which activities should be avoided. The PNGFA documents and the RIL guidelines were assessed to determine which planning and harvesting activities would be appropriate for small-scale forest management in PNG. The objective for this part of our research was to identify the specific activities that should be included in our recommendations and removing those that were more suited to industrial-scale forest management. The findings were reviewed by personnel from TFTC and PNGFA to ensure that the recommendations were appropriate. The final PNG small-scale RIL code of practice was written by Micah Scudder, Charles Tsiritsi, and Grahame Applegate.

Activity 3.4 Undertake combined demonstration of the main aspects of the revised RIL and Management Plans for clans in the field near Lae

The proposed methodology included the identification of a site with an existing Timber Authority (TA) or potential to obtain one (Approximately 12,500 ha total over a 50year cutting cycle with 250 ha harvested annually), that is within an economically feasible distance a of a mill. Ideally, the site was to be located in an area where TFTC had an area to be logged or within an existing timber concession, (coordinated with PNGFA, (Madang or Lae) and have already established relations with the communities. It was planned to involve Forestry students from UniTech for pre and post harvesting activities including; planning, RIL layout and measurement, mapping, forest inventory and capacity building of forest ecology related skills. There was also a workshop planned for UniTech students to demonstrate their skills learned in the activity as well as highlighting the results of the RIL and management planning activities to the PNGFA, communities and TFTC.

This activity was planned for 2020 and/or 2021 but COVID 19 curtailed any field activities in PNG that could be carried out in a safe manner by all researchers. Our revised plan involves a multi-day online workshop in September 2022. The workshop covered the outputs produced in Activity 3.3: small-scale FMPs, RIL procedures, and implementing a small-scale timber harvest. The workshop attendees include staff from TFTC, FRI, and the PNGFA.

Activity 3.5 Improved management of the eco-forestry system

Improvements to the eco-forestry management system were developed. These improvements were identified during project Activities 3.1, 3.2, 3.3, 3.6, and 3.7. A report was prepared summarising the research findings and recommendations for improving the eco-forestry system.

An assessment of the past eco-forestry operations was conducted with a literature review, interviews with key informants, and a thematic analysis of the findings. A Discounted Cash Flow (DCF) analysis of portable sawmill operations was conducted that utilized a mixed-methods approach. Key informants were interviewed from an eco-forestry NGO in Madang, from forest product businesses in Lae, and from staff at the TFTC in Lae. The data collected from the interviews was placed into a DCF model using Microsoft Excel software and Monte Carlo risk analysis simulation techniques. An analysis on value adding opportunities was undertaken to identify potential options for improving the low financial returns expected from milling rough-sawn lumber with portable sawmills.

To assess the existing timber markets available to FROs, and the constraints of the Timber Authority, we conducted a case study. This case study assessed the smallholder wood product value chain, the production costs of value-add wood products, and the reasons why FROs chose not to adhere to the TA process. The results of our research were reviewed to identify the features of previous small-scale forest management that were successful, and the areas that could be improved upon. We provided a series of policy options to mitigate the challenging areas.

Activity 3.6 Identify alternative marketing models and develop financial programming models to evaluate performance of harvesting and marketing operations.

Research commenced on data collection on the operational costs for timber harvesting, milling, and value-add production (Activity 3.6 and 3.7). The initial plan was to conduct time-and-motion studies for each of the wood product processes to get detailed cost estimates. TFTC indicated that this would not be feasible given the time requirements for a time-and-motion study and the time constraints of TFTC staff. The strategy was then modified, and in-depth interviews were conducted with each of the TFTC staff involved in the wood product production processes and then with small-scale wood product manufacturers located within Lae and nearby. Information from interviews with TFTC staff; TFTC Forester, portable sawmill and chainsaw operators, lumber grading & drying staff, machining, chemical treatment and sales staff, provided results which were essential for developing the proposed RIL component in Activity (3.3), 3.6 and 3.7: A summary of the methods is as follows:

Sawmills willing to participate in research were identified, multiple meetings were held with management and staff in collaboration with TFTC to understand operational costs; including harvest setup, logging, hauling and milling. We had planned to collect additional cost data for undertaking Reduced Impact Logging techniques in 2020, but this became impossible due to the Covid-19 pandemic where staff could not travel to the field.

Initially the methodology involved financial modelling in Excel and Linear Programming (if appropriate) to be developed and used to assess options. A discounted cash flow model using the Monte Carlo Risk Analysis Simulation was actually used by Micah Scudder to assess economic returns to forest resource owners and published in a peer-reviewed article.

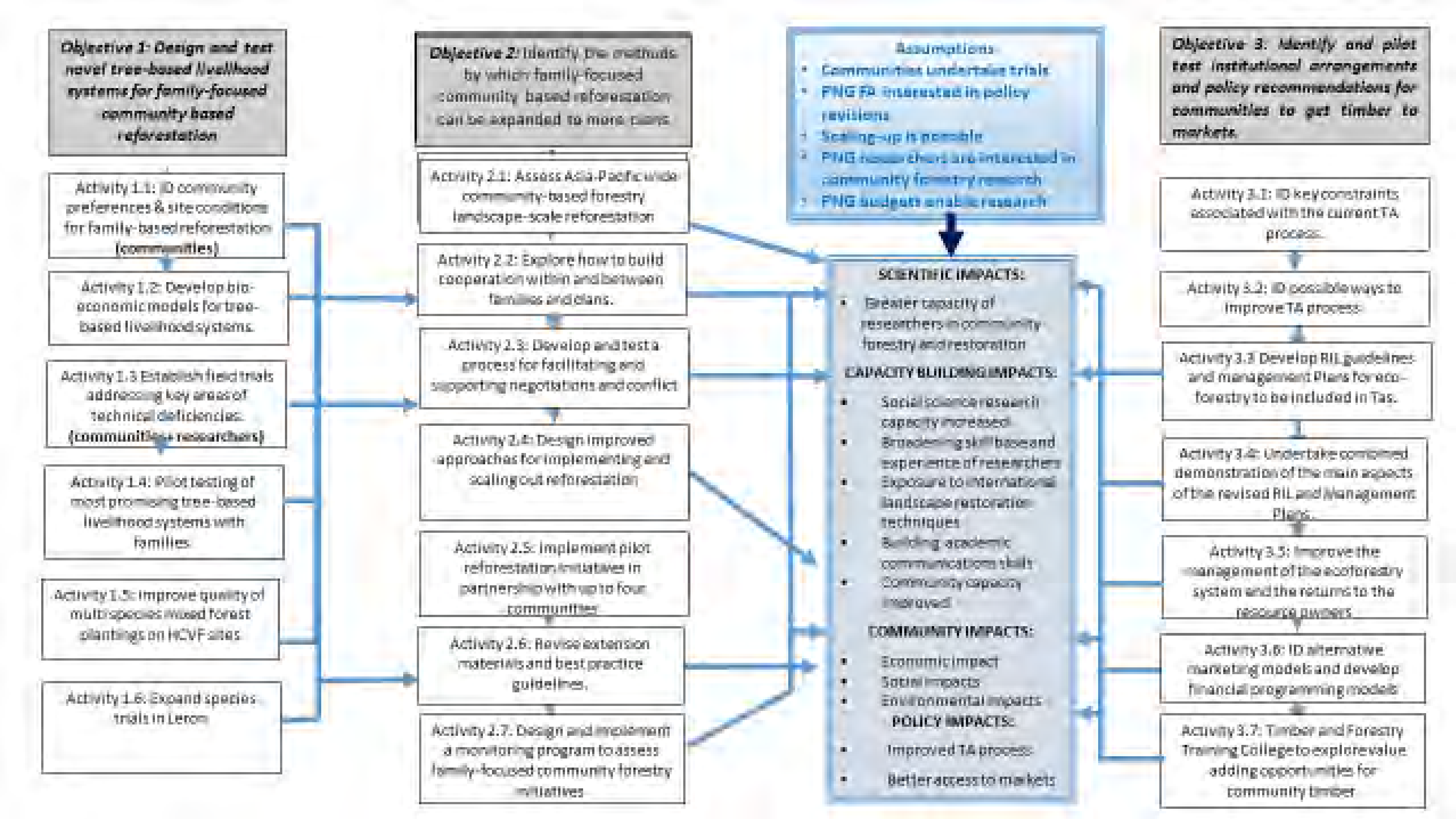
As part of this activity a Policy Brief was prepared by Micah Scudder, Claude Saliau, Dambis Kaip (PNGFA) and Grahame Applegate with consultations and discussions with other project partner staff within the PNGFA. At the suggestions of PNGFA, this policy brief was combined with the brief produced for Activity 3.2.

Activity 3.7 Explore value adding opportunities for community timber in local sawmills in Lae

As part of improving the returns to small holders, it was necessary to understand the value-adding opportunities for community produced timber in PNG. Several small-scale portable sawmillers and wood product manufacturers were interviewed. These businesses conduct timber harvests on community owned forests and value-add via processing the logs into a range of higher value products. The business owners provided a historical background of their business and the business model used involving harvesting cost, payments to landowners; wood processing equipment used, products produced, wood product sales prices and markets served. The business owners also shared information on the markets that are likely to provide the best opportunities in the future for small-scale wood product producers in PNG.

A report was produced on value adding opportunities for community timber production. A peer reviewed article on the potential of portable sawmills as a value adding opportunity for community timber production was also prepared.

Figure 2 Theory of Change Diagram



6 Achievements against activities and outputs/milestones

The project operated for 6 years, including a one year no-cost extension and faced a number of issues which seriously interfered with activities. Early delays included finalising partner contracts in 2017/18 (6 months delay) and subsequent funding (9-month delay) and research visas delays (3 years). These delays caused a loss of the field work. This led to out-planting in the RMV and species trials missing the first planting season (delayed by 2.5 years to 2019). Issues with distribution of project funds by the PNGFA, and TIFTC due to national budget issues, (8 -month period in 2018) where project funds were not provided to the PNGFRI or FA Eastern Highlands. Finally, the COVID outbreak in early 2020 led to numerous restrictions on local partners that contributed on and off until well into 2022. Travel restrictions, and local conditions in PNG, also prevented any visits by Australia-based staff from February 2020 until the end of the project in September 2022 (2.7 years).

The Outputs table shown below provides the information on the Research Activity as outlined in the original Project Document (column 1), a description of the Outputs, with any reports or published papers, policy briefs (column 2). The Report No. for the document is shown with the author and title in column 4. The actual documents with the report numbers are in numerical order in Appendix 1.

Objective 1: To design and test novel tree-based livelihood systems for family-focused community-based reforestation

Research Activity	Original / Completed Outputs	Planned & Actual *Completion Date* (bold)	Report No and Titles of Output Reports / Comments
Activity 1.1 Identify community preferences and site conditions for family-based reforestation	Conference Abstract on family-based reforestation	Dec 2017 ***Oct 2017***	01. Thom, M., Wiset, K., Borthwick, F., and Fisher, R (2019). **Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valley.** International FLR Conference Manila February 2019.
	Report on social science training workshop-Ramu	Feb 2017 ***Jan 2018***	02. R. Fisher**. Social science research training No.1** (Part 1 & 2).
	Report on social science training workshop-On-line	***Jun 2021***	03. R. Fisher, **Social science research training No.2**
	Report on community preferences for services required for home garden-based reforestation.	Oct 2018 ***Aug 2022***	04. R. Kagl, N. Wampe, M. Thom, and R. Fisher. **Preferences for family - based agroforesty in the Ramu-Markham Valleys.**
	Policy Brief to support the PNGFA to implement their community reforestation program.	Sep 2019	A Policy Brief was not prepared due to the extended time it took to undertake the research and then restrictions due to COVID -19 travel from Australia and meeting restrictions with relevant Department in PNGFA.
Activity 1.2: Develop bio-economic models for tree-based livelihood systems.	Report on bio-economic models for home garden-based tree systems	April 2020 ***Jun 2020***	05. M. Scudder, N. Wampe & Melinda Thom. **Bio-economic models for tree-based livelihood systems**

	Publication on cocoa / eucalyptus sp.based agroforestry system.	***Mar 2021***	06. Scudder, M., Wampe, N., Waviki, Z., Applegate, G., and Herbohn, J. **Smallholder cocoa agroforestry systems; is increased yield worth the labour and capital inputs?** *Agricultural Systems 196.*
	Conference Abstract on cocoa in Ramu- Markham Valley	***Feb 2019***	07. Single, C. and Baynes, J. (2019) ***Theobroma cacao*** **(cocoa) in the Ramu-Markham Valley: a strength, weakness, opportunities and threats analysis**. International FLR Conference Manila February 2019.
	Brochure	***Feb 2020***	08. M. Scudder, **Umi Agroforestry Demonstration**
Activity 1.3: Establish field trials which address key areas of technical deficiency in tree – based livelihood systems	Report on Establishment of Variable Spacing Trial- RAIL	Jul 2018 ***Jul 2020***	09. Z. Waviki. ***Commencement Report for Variable Spacing Trial (0.36 ha)-*** includes, specific design (common to all trials) layout, species, initial growth and mortality & maintenance schedules.
	Report on Establishment of Variable Spacing Trial- Kintinu (Goroka)	Jul 2019 ***Apr 2021***	10. W. Andasua **Commencement Report for a Variable Spacing Trial (0.36 ha)** and includes, specific design (common to all trials), layout, species, initial growth and mortality & maintenance schedules.
	Report - On-Line Zoom workshop with PNG partners on spacing trial data analysis.	Unscheduled in Initial PD ***Oct 2022***	11. M, Scudder **Species trial analysis on selected spacing / variable spacing PNG trials with R Software.**
	Report on Field Trial Establishment for PNG	***Aug 2022***	11a. N. Gregorio **Establishing Field Trials in PNG.**
Activity1.4: Pilot test most promising tree-based livelihood systems with families.	Livelihood agroforestry systems tested with a network of family-based trials established in Ramu /Markham Valley.	Sep2020 ***Mar 2019***	12. N. Wampe. **Commencement Report on the mixed species, multi-purpose agroforestry tree-based livelihood demonstration plot at Umi covering 0.5 ha (RMV).**
	A livelihood-based agroforestry system established as a family-based trial/ plot in Ifiufa, Eastern Highlands	Jun 2019 ***Jun 2019***	13. Vincianna Andrew. **Commencement Report on the agroforestry tree-based livelihood system at Ifiufa covering 0.16 ha and includes details on layout, species and management and measurement regimes.**
	A livelihood-based agroforestry system established as family-based trial at Marisin bridge, Eastern Highlands	Jun 2019 ***Nov 2019***	14. Vincianna Andrew. **Commencement Report on the agroforestry tree-based livelihood system at Marisin Bridge covering 0.16 ha and includes details on layout, species and management and measurement regimes**
	Report on early results and discussion on Umi Trial/Plot.	***Jun 2020***	15. N. Wampe. **Field Trip to Umi Agroforestry Plot**
	Report on Umi	***Jan 2020***	16. N. Wampe **Commencement Report on Umi demonstration**
	Report providing extension material on Q Seedling (developed by Dr Gregorio) produced for presenting at family/ community-based workshop at Daulo.	Sep 2020 ***May 2020***	17. Vincianna Andrew **Extension and Training for Q Seedling at Daulo in Goroka**
	Report on nursery training for clans in RMV	***Nov 2018***	18. C. Single. **Nursery Training at Atzunas community**
Activity 1.5: Report on the establishment of	Report on the establishment of the demonstration high species diversity nursery at RAIL.	Sep 2019 ***Mar 2021***	19. N. Gregorio. **Assessment of the Seedling Production System of RAIL Forest Nursery**

field trial from FST /2011/057 Improve quality of multi-species, or mixed species native forest reforestation on sites of high conservation value	Report on the establishment (**no evaluation as per the PD**) of the mixed-species trials designed to improve quality of reforestation at RAIL. Report on the establishment (**no evaluation as per the PD**) of the mixed-species trials designed to improve quality of reforestation at Goroka.	***Nov 2018*** ***Jul 2021***	20. N. Wampe: **Commencement Report on mixed-species trial (established in Nov 2018- 0.4 ha)** includes, specific design, layout, species, initial growth and mortality & maintenance schedules. 21. W. Andasua: **Commencement Report on mixed-species trial (established in September 2019 0.4 ha)** includes, specific design, layout, species, initial growth and mortality & maintenance schedules.
Activity 1.6: Maintenance and measurement of species trial established by FRI at Leron in FST/2011/057 and extend trial with additional agreed species	Interim report on variable spacing trial including the maintenance & interim tree measurements. Report on interim tree measurements Report on the additional trial (Mixed Species Trial) Paper in form of abstract and presentation focusing on a literature review of species performance in PNGFA trials	Jul 2018, 2019, 2020, 2021 ***Nov 2019*** Jul 2018, 2019, 2020, 2021 ***Jul 2021*** Jul 2018 ***Aug 2022*** Mar 2018 ***Feb 2019***	22. H. Morte. **Commencement Report on a Variable Spacing trial** using 4 species. at Situn and not Leron (as planned). 23. H. Morte. **Brief Summary of results covering 4 measurement periods.** 24. H. Morte. **Commencement Report on Mixed Tree Species Trial in Tikeleng** in August 2022. 25. Jeffrey, G., Morte, H., Applegate, G., Yelu, W., and Golman, M. **Tree species selection. One of the components for successful FLR in PNG.** Presented in International FLR Conference held in Manila, February 2019.

PC = partner country, A = Australia

Page Break

Objective 2: To identify the methods by which family-focused community-based reforestation can be scaled-out to a landscape scale

Research Activity	Original / Completed Outputs	Planned & Actual *Completion Date*	Titles of Output documents / comments
Activity 2.1: Assess community-based landscape-scale reforestation initiatives in the Asia-Pacific to identify key factors likely to impact success for scaling out.	Report outlining key drivers including impact of women of success of community-based landscape scale reforestation in Asia Pacific. Brochure on the Project Report on scoping study on causes of fire in RMV Abstract for a conference paper on initial observation of fire in RMV	Sep 2018 ***Jun 2020*** ***Feb 2019*** ***May 2021*** ***Feb 2019***	26. K. Wiset, J. Baynes, and G. Applegate. **Community – based landscape-scale reforestation initiatives in Asia-Pacific.** 27.M. Scudder **Enabling Community Forestry in Papua New Guinea** 28. N. Wampe, R. Fisher, G. Applegate and J. Baynes. **Anthropogenic fires in the Ramu-Markham Valley.** 29. Wampe, N., Fisher, R. and Baynes, J. **Anthropogenic fires in the Ramu-Markham Valley; underlying causes and motivations.** Presented in International FLR Conference held in Manila, February 2019.
Activity 2.2: Explore how to build cooperation within and between families and clans to enable landscape-scale reforestation.	Report outlines justification for why **Activities 2.2 and 2.3** have been combined and why pilot testing and scaling have been implemented in parallel. It explains how **Activity 1.4** (demo plots) forms part of the tree planting efforts for reforestation and or agroforestry.	Oct. 2018 ***Aug 2022***	30. R. Fisher, M. Thom, N. Wampe, and J. Baynes. **Agroforestry interventions at Ramu: The process and rationale for the approach**

	Abstract for a conference paper on reforestation and agriculture in grasslands in RMV	***Feb 2019***	31. Baynes, J., Mathe, L., Unsworth, W., and Applegate, G. **Synergies between forest landscape restoration and agriculture in the grasslands of Papua New Guinea** Presented in International FLR Conference held in Manila, February 2019.
	Publication on an analysis about gender issues related to the landscape restoration in the RMV	***Sep 2020***	32. Kanchana Wiset, Robert Fisher, Jack Baynes, Nathan Wampe, Melinda Thom, William Jackson and John Herbohn. **What could forest landscape restoration look like in the Ramu-Markham Valley of Papua New Guinea?** *Land Use Policy* 121 106322
Activity 2.3: Implement pilot reforestation initiatives in partnership with four communities in the Ramu-Markham Valley and Eastern Highlands	Report on reforestation, tree nurseries and rationale for reforestation, the community negotiation and the social investigation and extension process in 3 communities in the RMV	Sep 2019 ***Jun 2019***	**30. (see Activity 2.2 output)**
	Pilot reforestation activities commenced in two additional communities in Goroka in 2020 (No Report).	Sep 2020 ***Jun 2020***	Reforestation in Goroka is as follows: Lufa: (3 communities 21 families) 5 ha – 2020. Kafana: 3 communities 22 families) (6 ha) -2020
	Report outlining lessons, findings and the role of women in reforestation activities, and recommendations for future reforestation programs.	Aug 2021 ***Aug 2022***	33. M. Thom, K. Wiset, F. Borthwick. And R. Fisher. **Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valleys**
Activity 2.4: Develop extension materials and best practice guidelines outlining lessons key findings and recommendations	Best practice guidelines and training manuals on community reforestation	Sep 2020	34. N. Gregorio **Identifying Mother trees in Biodiversity Buffer Zones for Reforestation**
	Policy Briefs and meeting briefs to PNGFA on improved training materials to support their national reforestation program.	Sep 2020	A Policy Brief was not prepared due to COVID -19 travel from Australia and meeting restrictions with relevant Department in PNGFA.
Activity 2.5: Design and implement a monitoring program for community forestry initiatives	Report on designing and identifying key social, economic and biophysical indicators that are robust and simple enough to be measured at low cost for monitoring the impact of family-focused reforestation sites. The report combines interim information with the additional tree planting /monitoring data using Atzunas and Bopirumpun as examples.	Oct 2017 ***Jun 2020***	35. S. Scudder, G. Applegate, C. Saliau, N. Wampe, and B. Fisher. **Monitoring Program to assess Family-focused Community Forestry Initiatives**

PC = partner country, A = Australia

Objective 3: To identify and pilot test institutional arrangements and policy recommendations which improve access to formal timber markets

Research Activity	Original / Completed Outputs	Planned & Actual *Completion Date*	Titles of Output documents / comments
Activity 3.1 Identify constraints associated with the Timber Authority process	Report on the key constraints for communities to sell timber including key issues associated with the TA process	Jun 2018 ***Jun 2019***	36. M. Scudder, C. Saliau, and G. Applegate. **Constraints of the Timber Authority Harvest Permit and Options for Improvement**
		Jan 2019	**37.** Scudder, M. Baynes, J., Applegate, G., and Herbohn, J. **Addressing small-**

	Publication on small-scale forestry and informal markets in PNG		**scale forestry informal markets though forest policy revision: A case study in Papua New Guinea.** *Land Use Policy 88* (2019) 104109
Activity 3.2 Identify possible ways to improve the Timber Authority process for Eco-forestry.	Report covering options for revised TA processes and costs to enable communities to market their timber profitably. Policy Brief on TA Guidelines combined with timber market models and PNGFA regulations as part of Activity 3.6	Jun 2019 ***Jun 2019*** (Combined output with Activity 3.1) Sep 2019 ***Nov 2019***	36. (see Act 3.2 output) . **38.** M. Scudder, C. Saliau and G. Applegate. **The PNG Small-Scale Timber Informal Market - creating an enabling regulatory framework**. .
Activity 3.3 Develop Reduced Impact Logging (RIL) and management plans for eco-forestry to be included in the Timber Authority process.	Report outlining revised guidelines for RIL and management plans for clan-based operations.	Sep 2019 ***Jun 2020***	39. M. Scudder, C. Tsiritsi, and G. Applegate. **Reduced Impact Logging Guidelines for Small-scale Forestry in PNG**
Activity 3.4: Demonstration of the main aspects of the revised RIL and management plans.	Demonstration eco-forestry (small holder) /RIL activity undertaken in the field near Lae. 40. Report On-Line Workshop Workshop for TFTC, FRI, and PNGFA and Unitech students Five Guidebooks to provide guidelines for small-scale forest management planning and timber harvests with RIL techniques.	Nov 2020 ***Sep 2022*** Jun 2021 ***Sep 2022***	This activity did not proceed as planned due to COVID-19 restrictions and was replaced by an On-Line Workshop on small scale forest management 40. M. Scudder **Small-scale Forest Management Planning & RIL** . This Workshop was designed for TFTC, FRI, and PNGFA and Unitech Forestry students to training on the smallholder forest management plans, timber harvest plans, small-scale logging code of practice, and small-holder timber sales contracts. **The Workshop did not take place due to COVID-19** and was replaced by the On-Line workshop in Sept. 2022.Report No. 40. 41. M. Scudder **Guidebooks** 41a M. Scudder, **Forest management Manual.** 41b.M. Scudder. **Papua New Guinea Smallholder Forest Management template** 41c.M. Scudder. **Papua New Guinea Small -Reduced Impact Logging Code of Practice** 41d.M. Scudder. **Papua New Guinea Small-scale Timber Harvest Plan Template** 41e. M. Scudder. **Papua New Guinea Small-scale Timber Sale Contract DRAFT Template**
Activity 3.5: Improve the management of the selected eco-forestry system	Report on eco-forestry with recommendations for improving the eco-forestry management system for small holder forestry Publication on the management of the eco-forestry system in PNG	Aug 2021 ***Jul 2022*** ***Feb 2018***	42. M. Scudder and G. Applegate **Improved Management of the Eco-forestry System in PNG**. 43. Scudder, M., Herbohn, J., and Baynes, J. **The failure of eco-forestry as a small-scale native forest management model in Papua New Guinea**. *Land Policy* 77 (2018) 697-704.
Activity 3.6: Identify alternative marketing models and develop financial programming models	Report on financial and other models developed for the analysis of alternative harvesting and marketing models.	Oct 2018 ***Jul 2022***	44. M. Scudder and G. Applegate. **Identify alternative marketing models and develop financial programming models to evaluate performance of harvesting and marketing operations.**

to evaluate financial performance of harvesting and marketing operations	Publication on financial viability of portable sawmills	***Sep 2018***	45. Scudder, M., Herbohn, J., and Baynes, j. **Are portable sawmills a financially viable option for economic development in tropical forests.** *Forest Policy and Economics* 100 188-197.
	Publication on timber royalty to improve livelihoods	***Jun 2028***	46. Scudder, M., Baynes, J., and Herbohn, J. **Timber royalty reform to improve the livelihoods of forest resource owners in Papua New Guinea**. *Forest Policy and Economics* 100 113-119.
	Policy Brief on timber market models and improving financial returns to forest resource owners (see Activity 3.2)	***Jun 2019***	38. M. Scudder, C. Saliau and G. Applegate. **The PNG Small-Scale Timber Informal Market - creating an enabling regulatory framework**
	Report On-Line Workshop	***Jul 2022***	47. M. Scudder, **Forest Financing**
	Workbook on forest financing	***Jul 2022***	**48.** M. Scudder. **Finance Training Workbook**
Activity 3.7: With the assistance of Timber and Forestry Training College and the local sawmills in Lae to Explore value adding opportunities for community timber.	Report on benefits and beneficiaries for timber-based value-adding opportunities for eco-forestry timber	Sep 2019 ***Jun 2020***	49. M. Scudder, C. Tsritsi, C. Saliau, and G. Applegate**. Value Adding Opportunities for Community Timber Production in Local Sawmills in Lae.**

PC = partner country, A = Australia

7 Key results and discussion

A summary of the results and findings are as follows:

- Tree species trials require a long-time commitment in most cases to obtain meaningful results. A long-term commitment from ACIAR and the partners is required and should be incorporated in the research partner's monitoring and maintenance program following the completion of the Project. This should be agreed to with partner organisations prior to the Project commencing.

- A similar point can be made about the social processes involved in extension activities to identify community interests and negotiate with communities about activities.

- Understanding tenure and decision-making processes is essential to any reforestation or agroforestry interventions. Findings in the RMV make it clear that both clans and individual farmers are essential to land-use decisions. Clans own the land, but do not usually engage directly in land-use or economic activities. They allocate land to clan members who make decisions about the use of land and the activities that take place on it. This means that interventions regarding reforestation need to involve both clans and families or small groups of close kin.

- Individual families will generally be the direct beneficiaries of efforts to reforest grasslands rather than the clans.

- Extensive investment is required in developing social and other "capital', for a landscape approach to forest restoration to be feasible. In summary, it doesn't have to be centrally managed, but can rely on lots of little actions which can add up to FLR.

- Highly targeted, family-based, assistance may be more effective than participatory community-wide approaches to engagement.

- Local communities are heterogeneous in terms of interests. It is essential that outside agencies involved in extension understand the variety of interests and stakeholders within the population rather than assuming shared interests.

- Training, material assistance and institutional support may be initially effective in promoting collective action for FLR, but heterogeneity may re-emerge as a disruptive influence if well-intentioned extension activities create or exacerbate existing social tensions.

- Standardising case study data collection methods across the ACIAR Projects in the Philippines and PNG has been important to better identify lessons learned in both situations for improving our understanding how best to implement FLR. Use of methods such as stakeholder interviews and landscape visualization have proved to be useful.

- Identifying preferred tree species for clans and families to plant risks limiting options to the species families know or have heard about which may be unavailable or unsuited to local conditions. A better strategy involves identifying what services and benefits families and clans want to obtain from farm-based agroforestry and then discussing specific options. Individuals have a variety of needs and pre-designed agroforestry packages will need to be broad in scope to be adapted by individual farmers.

- Women strongly prefer agroforestry or tree plots to be in proximity to their homes and not to be too large. Given that any tree planting will impact on women's labour, this is an important result for upscaling, designing and locating agroforestry systems in the RMV.

- Women and men often have broadly different preferences for tree-based land use systems. Women tend to prefer planting trees mixed with food crops, not in rows. Men tend to prefer trees to be planted in rows to provide shade for cash crops.

- Men are generally more active in clan-level decision making. Women, however influence their decisions and are also heavily involved in household level decisions about gardening. However, there is variation and women influence decisions in a variety of ways.

- Cocoa agroforestry technologies that have been found to increase cocoa yield require additional labour and capital inputs that result in a decreased hourly wage equivalent being earned by smallholders.

- Organizations involved in eco-forestry pursued an operational model primarily focused on producing rough-sawn sustainably certified lumber for the international market; but this model failed. Producers struggled to meet the quality and quantity demands of international lumber buyers and hence financial viability.

- Using portable sawmills to produce rough-sawn lumber is highly unlikely to be financially viable if an even distribution of the trees at the harvest site were milled. The value-added wood products that provided the largest financial return in local markets were tongue & groove flooring and weatherboard.

- Timber royalties designated by the PNGFA are at fixed-rates by species. The real value of the timber royalties has declined by 51% since 1990, with some species showing declines as much as 67%. The results of the fixed-rate royalty applied to PNG timber means that the real value of the financial returns that forest resource owners receive from timber harvests is becoming smaller each year. An unintended consequence of the low royalties paid to forest resource owners has been the development of an informal sector of technically illegal small-scale timber harvesting in the native forests.

- The Timber Authority permit was designed for industrial-scale logging operations and are not the appropriate scale and or able to meet the immediate cash needs of FROs. As such, most FROs do not obtain a TA and operate within the informal market outside of the regulations and view of the PNGFA. The small-scale wood product manufacturers that participate in the informal market have been able to capture most of the timber value and have a monopoly on market price information.

Each of these key results is discussed below.

7.1 Tree species trials

Variable spacing trials under Activity 1.3 (PNGFA Goroka and RAIL) and Activity 1.6 (FRI) have been established at Situn, RMV and Goroka. The trials form part of a series of similarly designed trials in the Philippines and in ACIAR FST/2012/057. The establishment of the trials have been documented in the form of Commencement Reports, which provide details of the planting date, design and layout and maintenance and monitoring schedules. The trials comprise four species in a variable spacing design (modified Nelder Design), with the objective of assessing survival and performance at ten different spacings, ranging from 0.3 m to 7.5 m. Each trial area is 0.36 ha. All new trials will be designed with buffer rows surrounding the net plots which aids in the analysis using R Studio.

Mixed tree species trials with similar designs for comparison have been established at Goroka by PNGFA Goroka and at Ramu by RAIL under Activity 1.5 and near Lae by FRI under Activity

1.6. Survival and growth data is collected regularly from all project trials, with the early results providing a basis from which to evaluate initial responses to species mixtures, spacing and other measured parameters.

The trials in Activity 1.3, 1.5 and 1.6 were designed to facilitate improved silviculture requirements for community-based reforestation, where optimum planting spacing for tree species are currently unknown for different management objectives and rotation requirements. In addition, the mixed species designs which have been also used elsewhere are designed to identify how different species perform when gown with different species. This concept is based on previous research in Australia by Lamb et al. (1998). This is information is important for use in both an agroforestry system as outlined in Activity 1.4, as well as in mixed species plantings required for High Conservation Value plantings on degraded stream banks and buffer zones.

The data from the trials is being collected and the measurements will be analysed in Microsoft Excel and R software to assess the results. A Workshop using R was undertaken in September 2022 using data from the Spacing Trial and Setun and the Mixed species trial at Goroka established in FST/ 2012/057 which is now 5 years old, to train the partners how to use R to analyse their own data from their trials.

7.2 Family focused tree-based livelihoods

7.2.1 Family preferences

It is important to understand what local people and communities want from project activities. This means understanding what different stakeholders need and this especially requires an understanding of gender differences. The report by Kagl et al. (2019) and the PhD research by Wiset et al. (2022) documents the significance of the differing outcomes people desire from interventions.

An underlying concern was that identifying preferred species risks limiting options to species families know, which may not be available, may be too expensive or may be inappropriate to local conditions such as climate, soil or altitude. This approach risks leading to a “shopping list”. Identifying what services and benefits families and clans want to obtain from farm-based agroforestry is more useful and allows exploration of a wider variety of practically available options. The result is a broad understanding of the expectations of communities from agroforestry and that individuals have a variety of needs and that pre-designed agroforestry packages will need to be very broad in scope to be adapted by individual farmers. An important finding is that women strongly prefer that plots should be in close proximity to their homes and should not be too large. Given that the proposed plots will impact on women’s labour, this is an important result for upscaling, designing and locating agroforestry systems in the RMV.

The study on family tree- plantings involving individual family-based agroforestry systems with cocoa indicated that with current prices received, smallholders are receiving an equivalent hourly wage that is less than the minimum wage in PNG. In addition, the progressive addition of labour inputs and capital outlays of the higher input based cocoa systems results in hourly earnings that are less than the low input systems, or current system being practiced by smallholders in RMV. These decreased hourly earnings may explain the low adoption of these technologies. The results indicate that the additional evaluation criteria used in this analysis (return on labour, mean labour hours/day, and mean annual capital outlays) should be incorporated in other future evaluations of agroforestry systems to better understand the management activity requirements of smallholders from the view of labour and capital input costs

Financial models have been developed for multi species agroforestry systems for rural landowners in the Ramu Valley. The purpose of these models was to compare how different land use alternatives can impact the livelihoods of the landowners. The financial criteria to evaluate these different models was net present value (NPV), land expectation value (LEV), return on labour, and average person hours per day worked. These financial criteria were selected as they allow evaluation of agroforestry systems from different perspectives. NPV and LEV are commonly used criteria for ranking the present value of different land-use investments. These criteria may not always be appropriate for evaluating agroforestry systems because the landowners are subsistence farmers and there is technically no financial cost for their labour inputs. Hence, return on labour and average person hours per day were incorporated as evaluation criteria. The agroforestry systems that have the highest NPV and LEV did not always have the highest return on labour, which could be a more important criteria from the perspective of the landowner. Additionally, some of the agroforestry systems that had the highest average person hours per day would make these systems unfeasible for some landowners due to time constraints and/or smaller household labour availability. Using these additional criteria allowed to better assess which land-use alternatives are most appropriate for the specific situation of individual landowners.

7.3 Clans and Gender based land use decisions

Clans and land use decisions: As has been pointed out above, clans allocate plots of land to clan members. Clans do not generally act collectively on economic activities on clan land. The activities and who and what is involved are determined at the family level. Clan leadership is usually not inherited or by election. It is usually achieved by prestige and reputation. Sons of leaders may achieve leadership by association with their father's prestige, but this is not formal inheritance. Technically the leadership is achieved rather than ascribed. There are often several leaders who have authority on the basis of their reputation and social networks. Land use decisions are not usually made by "committees" of clan leaders but informal processes.

Gender: While decision-making about land use at the clan level tends to be dominated by men (as land tenure is patrilineal in the RMV), this can be overstated as women do influence decisions in the background. Women are heavily involved in decision-making about crop choices and other aspects of land use in the gardens they manage. Importantly, they can often "vote with their feet", by not following decisions, when decisions made by men impose unacceptable labour requirements on them.

An important finding of implementing the tree-based livelihood systems tested under Objective 1 with a wider number of clans is separating the 'pilot testing' from the wider implementation. Separating these two aspects has been demonstrated to be unrealistic both for practical and methodological reasons. In fact, pilot testing and the expanded implementation have been taking place in parallel. Firstly, the pilot testing did not commence until after the 2018/2019 wet season (November – March) due to the delayed project starting date and the pilot testing of community reforestation plots has therefore not been fully implemented and certainly has not been completed. Expanding implementation of field plantings cannot be based on incomplete results. The second reason is that the pilot process makes sense if it involves a wider variety of interested farmers. Identifying individuals to collaborate with necessarily involves cooperation with clans, at least in seeking agreement about activities. Selecting very limited numbers of individuals following extensive discussions and negotiations with and within communities raises expectations. These negotiations may identify additional individuals with potential interest in trial plots. Restricting numbers frustrates expectations.

7.4 Community-forestry in the Asia Pacific region

A study of community-forestry revealed that many of the large-scale reforestation activities in the Asia Pacific region that have reforested hundreds of thousands of hectares involving communities have been funded and managed by central governments, with the communities supplying the labour for tree planting. A close look at the policies in many countries relating to community-based forestry indicate that little attention is given to tenure rights, which are usually vested in the government and provide little in the way of supporting “collective action” or smallholder forestry on a landscape scale. This approach has never-the-less been seen by many as being successful, as trees have been established on degraded forest land.

In most countries in Asia Pacific, even in Melanesia where the government does not own most of the land or forests, the capability of communities to actually have effective management power to manage their community land limits their scope to successfully undertake community-based reforestation or FLR to combat the impacts of deforestation forest degradation and poverty. The study also found the terms community-based forestry, or community forestry are generic and cover many activities involving reforestation or the different forms of “FLR”. In Asia Pacific, much of the scientific literature, as well as the different institutions’ reports and government policies have titles including the words, ‘FLR’ or ‘community-based forest management’, but what is often described in the documents is reforestation, managed by central or local governments, with communities mainly involved to plant the seedlings. There are few examples apart from perhaps Nepal and the smallholders in parts of Indonesia which can, under current definitions be considered as community forestry, where collective action by communities or by individuals is undertaken, for managing forests on their own land.

7.5 Fire in the Ramu – Markham Valley

Fire is a major concern in many parts of the Asia Pacific where monsoonal climate patterns prevail and where forests have been degraded by repeated fires, resulting in large areas dominated by grasslands. It is therefore to be expected that fire is a major element in influencing land cover in the RMV and Eastern Highlands much of which is dominated by grasslands. A scoping study by Nathan Wampe at Ramu, carried out as a project activity, focused on improving our understanding of the underlying causes of fire around the RAIL operations. A preliminary typology was developed to replace the common assumption that fires are mostly lit just because people like lighting fires. Many fires are lit for purposes of land management or hunting. Fires also arise from conflicts over land or other assets and is used as a weapon in conflict resolution. Despite common assumptions (prejudices) relatively few ignitions occur for entertainment. This research was undertaken as preliminary/scoping research and has highlighted the need for follow-up research and building on the research methodologies that have been developed by ACIAR and other fire research projects in Indonesia.

7.6 Cocoa agroforestry technologies

In Papua New Guinea, pest and disease management systems have been developed to provide improved yields and revenues, but there has been limited uptake. An ‘Integrated Pest and Disease Management (IPDM) system was previously developed that had four categories for smallholder cocoa management. The first IDPM system (low inputs) is representative of the existing smallholder cocoa management practices. The remaining three IDPM systems (medium, high, and maximum) require increased activity inputs. It was estimated that incorporating the other three IPDM systems would provide greater returns to smallholders. We hypothesized that the low uptake of these systems may be due to the improved yields not being sufficient to justify the required increase in labour and capital inputs. Our objective was to assess if the integrated pest and disease management systems were financially viable. We developed four DCF models to simulate the four IPDM cocoa systems. Monte Carlo risk analysis simulation was incorporated into the DCF models to address variables with inherent uncertainty. The results demonstrated that the progressive addition of labour inputs and capital outlays of the pest and disease management systems resulted in mean hourly incomes that are less than currently being received. These decreased hourly earnings may explain the low adoption of these technologies.

7.7 Eco-forestry operational model assessment

Beginning in the 1990s, six organizations attempted to mitigate the deforestation and forest degradation occurring in PNG by facilitating small-scale native forest management by Indigenous forest landowners. All six organizations utilized an 'eco-forestry' approach, involving selective harvesting of timber combined with the milling of timber by Indigenous forest landowners using portable sawmills. The lumber produced was sold into local and international markets as sustainable certified under Forest Stewardship Council (FSC) principles. The use of portable sawmills was also intended to provide the landowners with a greater financial return compared to the timber royalty payments they could receive from logging companies. We conducted a literature review and interviews with key informants from the eco-forestry organizations and the PNG Forest Authority to assess the effectiveness of variants of the portable sawmilling model. We found that each of the six organizations were unsuccessful in developing a financially viable model for small-scale native forest management by Indigenous forest landowners in PNG. All the Indigenous landowners were unable to continue their portable sawmill operations once the donor funding of the eco-forestry organizations ceased. In addition, the operators of portable sawmills struggled to produce lumber that met the quality and quantity demands of buyers, who ultimately ceased purchasing the lumber. Furthermore, the Indigenous landowners struggled to adhere to the FSC principles, resulting in a loss of FSC certification. The study identifies a need for a new small-scale native forest management model in PNG. We recommend that future research involve collaboration with private sector businesses and professionally trained operators to inform the development of a small-scale forest management model which is financially profitable while also adhering to the principles of eco-forestry.

7.8 Financial analysis of portable sawmill operations in tropical forests and value-add opportunities

Using portable sawmills to produce rough-sawn lumber is highly unlikely to be financially viable if an even distribution of the trees at the harvest site were milled. The variable processing costs of portable sawmills are very high relative to the average sales prices of rough-sawn lumber. It was discovered that only a small selection of timber species had per unit sales prices that were greater than the per unit production costs. This finding illustrated that the species composition of the harvest site was a critical factor for achieving financial viability. The high level of species diversity of PNG's forests emphasized the importance of harvest site selection. Harvest site selection was also affected by the distance to market due to high lumber transportation costs. The research also discovered that maximizing daily log input and A grade lumber recovery were also critical factors for achieving financial viability with portable sawmills. The advent of a desired timber species composition at the harvest site did not guarantee financial viability. This finding highlighted the importance of competency-based training for small-scale timber harvests and portable mill operations.

We found that the financial viability of portable sawmill operations could be greatly improved if further value was added to the rough-sawn lumber. We determined that the value-add wood products that offered the best potential opportunities are T&G wood flooring (made from *Pometia pinnata*, and *Intsia bijuga*), weatherboard (made from mixed softwoods, and architrave made from mixed hardwoods. We found that these products had the largest profit margins and require a larger volume of use per housing unit relative to D-mould. Structural lumber products that are in demand should still be produced, but we recommend that the cutting patterns for milling the logs focus on producing flooring, weatherboard, and architrave pieces. In addition, focus on these value-add products can act as a hedge against the larger sawmills that are able to produce rough-sawn lumber products at lower costs.
We suggest that value-add wood product manufacturers strive to produce the highest quality T&G flooring and weatherboard within the target market. Opportunities for improving product quality can be achieved with the purchase of modern machining equipment, improved drying and grading standards, and improved chemical treatment procedures. We recommend that further research be conducted to identify the specific product attributes desired by the target market related to these quality improvement opportunities. We also recommend that further research be conducted to identify the service attributes desired by the target market. Some examples of service attributes are; installation instructions included with the product; installation training; product delivery; prices; payment options; and sales reps being available.

7.9 Assessment of timber royalties paid to FROs

During the last decade, annual timber harvest volumes in the formal market have averaged 3.4 million cubic meters (m^3). Approximately 90% of the timber harvested is exported. The logging companies are required to pay timber royalties to the customary landowners. These royalty rates have minimum fixed values that vary by species. The fixed rates were initially set in 1991 at 10 PGK per m^3 for all species. In 2008, the Forest Minister increased the rates for select species in the Group 1 category. The royalty rates for species in Groups 2, 3, and 4 have not changed since 1991.

PNG has experienced an average annual inflation rate of 7% since 1991. Since the timber royalties are fixed rates by species, the weighted average real value of all the timber royalties has declined by 53% from 1991 to 2020. The real value of royalties for Groups 2, 3, and 4 species have declined by 70% from 1991 to 2020, since the rates for these species have never been increased despite representing an average of 35% of timber harvest volumes. By comparison, the log export duties collected by the PNG government are calculated with a progressive tariff rate based on the Free on Board (FOB) market value of the logs. This protects the tariff rate from the erosion of real values caused by inflation. The result of the fixed-rate royalty is that the real value of the financial returns that FROs receive from timber harvests on their lands is getting smaller every year. An unintended consequence of the low royalties paid to the FROs has been the creation of an informal market of small-scale timber harvesting in the country's native forests.

In late December 2021, Circular Instruction No. 25/2021 by the PNG Forest Authority was issued as a public notice for the timber royalties to be increased by 20%, effective as of 1st January 2022. If the timber harvest volumes by species in 2022 is representative of the average for the last decade, the average real value of timber royalties will increase to approximately 18.40 PGK per m^3.

7.10 Constraints of the Timber Authority for Timber Harvesting

The 1991 Forestry Act does not clearly define regulations for timber harvests less than 500 m^3. The Act implies that individuals can harvest up to 500 m^3 per annum for personal use, but not for commercial purposes. The Forestry Act does not define what qualifies as commercial use versus personal use. The vagueness in the wording has resulted in different interpretations of what the intent is for harvests less than 500 m^3. The predominant view is that personal use refers to harvesting timber for constructing personal homes, other personal buildings, and for fuel wood. Commercial use refers to the exchange of timber for money and/or other goods, which is predominantly viewed as a violation of the regulations.

Most FROs do not obtain a Timber Authority (TA) because it does not fit their timber harvest needs or their operational timeline. Most portable sawmillers harvest less than 225 m^3 per year. The maximum annual operational capacity of most small-scale timber producers using a portable sawmill is typically less than 500 m3. The TA is for timber harvests between 500 m^3 to 5,000 m^3 per year. In addition, most participants are not aware of the TA application process procedures or have the financial means to provide the required performance bond. Furthermore, most FROs sell their timber when they have immediate monetary needs. They view their forests as a bank automatic teller machine (ATM) and make a withdrawal (small-scale harvest) periodically when needed. The most common immediate cash needs identified were:

- School fees: All expenses related to school, any actual school fees, project fees, stationary, uniforms, and transportation to school.
- Store-bought goods: Consumables that FROs cannot provide for themselves such as clothing, packaged rice, and canned meat.
- Ceremonies, such as weddings and funerals.
- Home construction: Lumber materials and non-lumber materials; nails; plywood; metal siding; roofing materials; doors; windows; and window screens.
- Christmas celebrations.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Important impacts have emerged from the community agroforestry research and the eco-forestry (community forestry enterprises) research where the costs and profitability of the current small-scale forestry in natural and secondary forests were identified. A paper was prepared on the evaluation of the current small scale forestry model and identified how small-scale community forestry involving producers and can improve value-adding opportunities for community-based timber production in PNG.

An emerging scientific impact comes from our new extension approach, i.e. with community leaders' support, to develop a client base of families (rather than communities) and provide technological assistance directly to these families. This approach is not new but it is new to agroforestry in the RMV. Hence it represents a significant departure from (largely failed) attempts to improve agroforestry adoption through intra- or inter-clan collective action. This new approach was trialled in two villages and initial results indicate increasing adoption and ascertaining families' preferred species mix, planting style and scale. This may enable us to scale up agroforestry extension in other villages.

The key constraints of the TA process and the resulting recommendations to improve the TA process have been prepared in a Policy Brief co-authored in association with project partners, the PNGFA. The review on the financial returns received by forest resource owners (FROs) from timber harvested on their land and milled with portable sawmills has also been prepared in a Policy Brief co-authored in association with project partners, the TFTC. At the suggestion of PNGFA, these policy briefs were combined, and will form the basis of revising policy to provide greater benefits to smallholders.

8.2 Capacity impacts – now and in 5 years

The project has placed considerable emphasis on social science research training and mentoring of project staff. The reason for this emphasis is that project partners generally had sound qualifications in forestry and/or environmental science, but had very little, if any social science expertise. Three social science workshops were held. The first workshop was held at Ramu in January 2018 and involved staff from collaborating partners. A second workshop was held in March 2018 at Visayas State University, Leyte, The Philippines. This was held in collaboration with ACIAR project ASEM/2016/103 based in the Philippines and was one of two parallel workshops held for researchers from both projects. The third social science workshop was an online workshop held in April 2021.

The social science training was complemented by ongoing mentoring on social science methodologies both at Ramu and Goroka. A positive outcome of the capacity building in social sciences is that Vincianna Andrew is now undergoing a masters' program at Curtin University on a social science-based topic. This is likely to be of longer-term benefit beyond the project.

The project put on an 'Introduction to Forest Finance' online workshop on April 5th to April 7th 2022. The workshop was attended by TFTC, PNGFA, PNG FRI, and RAIL staff. The workshop provided attendees with training in financial mathematics, DCF spreadsheet analysis, and cost-volume-profit analysis. A workshop workbook and spreadsheet templates were provided to all attendees so that they can apply the finance lessons learned to other forestry projects. It was pleasing to note that the Economist at PNGFA was particularly interested in understanding more on the topic.

The nursery training and improved nursery design held for the communities in the RMV was observed to have led to individual farmers applying the techniques in micro-nurseries. While the impact of such activities has not been measured, it likely amounts to a positive if unintended consequence of project training and the unmeasured demonstration effect potentially amounts to a longer-term impact. As mentioned in Section 8.3, such impacts can only be measured by deliberate post-project impact assessment.

The research on species trial training has also involved demonstrating the importance of documentation when it comes to research. As such, the project has instigated Commencement Reports, Interim Summaries for all project field trials and demonstrations. The process is being taken up by the partners at RAIL and PMGFA Goroka as part of their research protocols. More specifically, the members of the RAIL team have developed significant capacities in social science field skills and negotiation with communities. This is evident in the extent to which they plan, implement and report on activities jointly planned with and mentored by USC researchers.

Four local partners of the project attended the Forest and Landscape Restoration International Conference held in Manila in February 2019. The preparation and presentation of papers to an international audience as well as participation in a major international conference, represented an important contribution to their development of research capacity. A total of six presentations were made by PNG project staff or partners, each focused on PNG or included PNG content. Of these, four presentations were made by local partners from RAIL (three) and FRI (one). From the project point of view the presentations by the PNG partners represented an important contribution to the development of research skills including paper writing and presentations.

The Directors of FRI and PNGFA recognize that junior researchers and middle-level managers lack capacity and experience in research design, data analysis, and scientific writing. A Small Research Activity (SRA) was prepared for ACIAR in response to their request aimed at improving publication quality and quantity from all PNG partners. The SRA was unsuccessful in 2019. Subsequently, the Project joined with another ACIAR Project in Indonesia, FST 2016 144 and a NASA Peat Fire funded project in Indonesia to develop a 17-week training course on tools required to enhance scientific publications. The training has equipped the researchers from RAIL PNGFA and TFTC with the necessary skills to analyse their own field data and to prepare maps for publication. No FRI researchers were available to undertake the training to support the preparation of their peer-reviewed publications.

Training by the Project for communities and research staff in the partner organisations was undertaken in quality tree seedling production, species research trial design and measurement improvements for high biodiversity seedling production in nurseries and publication enhancement training for the research partners have been beneficial to the partner organisations as well as the communities in being able to provide high quality seedlings for reforestation and agroforestry.

Q Seedling Training.

Community members in the RMV and the Eastern Highlands near Goroka have been trained in nursery techniques and used new gardening models incorporating trees with food crops. The project team has noted that there is a demonstration effect that is not easily monitored. In the RMV people from the Bopirumpun community, led by one individual (champion farmer), with a certain level of influence in the community and not originally targeted by the project, commenced agroforestry activities on his own initiative with support from RAIL and the Agriculture Dept. His actions which are now supported by the Project, seems to have been a factor in other families in the village taking up reforestation activities. The activities of some families in the community included a strong collective element. The sharing of information (skills, techniques, practices) with regards to reforestation between community members is a key significant social impact especially for RMV. Identification of and support for a champion farmer such as in Bopirumpun, who has carried out numerous information sharing activities to stimulate reforestation participation, has highlighted the importance of this approach. The activities show some level of network in information sharing within the community that is important to identify along with a better understanding of the driving factors. The high species diversity nursery at RAIL can be perceived as a FLR –specific asset that incorporates value chain activities, i.e. sustainable practices and/or natural resource restoration, e.g. riparian restoration, soil and biodiversity conservation.

In the Eastern Highlands, training activities had unplanned impacts in other provinces due to networking between a training participant and networks extending beyond the province. Unplanned (but not necessarily unexpected) impacts are difficult to monitor and quantify, but perhaps are the most important social impacts of project activities. This topic is being researched further and is planned to be part of the topic which Vincianna Andrew will study with her JAF Scholarship.

8.3 Community impacts – now and in 5 years

Given that the time available for the project to develop and test models of agroforestry systems was minimal, it was quite unrealistic to implement a separate process of "scaling up". As discussed in the report on Agroforestry Interventions at Ramu (Report No. 30 in Appendix 1) the process of development of and testing of systems was necessarily highly time consuming and could not be expected to provide demonstrated packages in a short time. One reason for this is that the processes of negotiation between the project and clans and within clans is complex and unpredictable. Another reason is that it takes time for plantings to develop enough to demonstrate benefits. This is essential where trees are involved. The loss of two years of intense project activity due to COVID compressed this process further.

Nevertheless, the uptake by community members, even at the testing stage increased fairly rapidly as new farmers observed the activities of others. Importantly, people adapted the extension guidelines, modifying mixes of trees and agricultural crops. The role of the demonstration effect is difficult to measure and even more difficult to predict over time. In the case of the Umi demonstration plots, visitors passed by from a variety of locations and follow-up and attribution of impacts was unrealistic. Interestingly the take up of project messages was very rapid at Bopirumpun, probably because of the demonstration effect from other project sites, combined with high quality local leadership.

Predicting community impact five years after the project ends is essentially speculative. It would be more useful to carry out a review of impact five years after a project ends. An excellent example of this an impact assessment carried out in relation to an NTFP project in the Lao P.D R. Five years after the project closed the impact assessment (Ingles et al. 2006) showed that livelihood benefits had continued to accrue as innovations under the project had been maintained. It was also found that the project methods had been adopted in activities elsewhere in Lao P.D.R. This was partly a result of the demonstration effect on visitors.

One of the most important impacts of the research into small-holders involved in natural forests was that the eco-forestry model previously practiced in PNG is unsustainable and provides little incentive to communities for optimising timber value from their forests. The research indicates there are no current "eco-forestry" operations being undertaken in PNG and these are only possible if highly subsidised by NGOs and their finance. Recommendations for improving small-scale forest management operations for areas outside the Project area were provided.

It is well known that social science research can sometimes have negative impacts on communities and individuals in cases where personnel data is exposed and distributed. In order to safeguard the rights of communities with whom we work, the following requirements of the *National Statement on Ethical Conduct in Human Research,* USC has a process of Human Ethics Approval which is a useful blueprint for research in rural communities.

The results and implementation of the agroforestry trial on land belonging to Jennifer and Bau Waiko with other local landowners at Umi will benefit the other clans in the region; especially communities displaced from a major natural disaster that occurred further to the north and are living in the area. They will benefit from the new knowledge gained from the agroforestry demonstrations involving combining food and long-term tree crops. The trial was intended both as a trial of varying agroforestry crop mixes and as a demonstration plot located on a road used by passers-by from communities. The longer term impact on the agroforestry practices of visitors cannot be predicted. Follow-up would be needed.

As part of the efforts to improve livelihoods through community-based reforestation in the Ramu area, the project has been working with selected communities to identify farmers interested in agroforestry and to negotiate land uses with the clans who own land. One aspect of this is training which has focused on establishment of small tree seedling nurseries in the villages of Atzunas, Marawasa (Karanas hamlet) and Bopirumpun. These nurseries are sources of tree seedlings for distribution to individual farmers and agroforestry trial plots. The knowledge from the nursery training has already been observed to influence expansion of the tree plantings in Atzunas and Bopirumpun and other nearby villages.

In accordance with our findings in the previous project that farmer-grown seedling quality was universally poor, improving seedling quality has been a key focus of extension activities. PNGFA and RAIL staff were trained and Vincianna Andrew (at Goroka) and RAIL researchers have provided continual remedial nursery training, via home visits to interested farmer participants. This capacity building with technical assistance and through demonstration plots has enabled for example, the community members at Atzunas, Umi and in Goroka to be able to produce cash crops as well as cover crops for their cocoa and coffee crops, thus leading to greater production. These RMV agroforestry systems were analysed to determine the different costs and benefits from the different options. The average hourly earnings were estimated for each system, which included how the forecasted hourly earnings will change over time. In addition, linear programming models were developed to identify the financially optimal mix of these agroforestry systems subject to labour and land constraints.

Timber royalty rates have minimum fixed values that vary by species. The fixed rates were initially set in 1991 at 10 PGK per m^3 for all species. In 2008, the Forest Minister increased the rates for select species in the Group 1 category. The royalty rates for species in Groups 2, 3, and 4 have not changed since 1991. The project analysed the timber values being paid to FROs and the affect that inflation has had on the real value of royalties received. The findings were published in a peer-reviewed journal in 2019. In late December 2021, Circular Instruction No. 25/2021 by the PNG Forest Authority was issued as a public notice for the timber royalties of all species groups to be increased by 20%, effective as of 1st January 2022. If the timber harvest volumes by species in 2022 is representative of the average for the last decade, the average real value of timber royalties will increase to approximately 18.40 PGK per m^3 in 2022, an increase of approximately 3 PGK per m^3 from the previous year. If timber harvests volumes remain similar to the last five years (≈ 3.4 million m^3 per year), the increase in timber royalties received by FROs will be approximately 10 million PGK per year, until the real value is again eroded by inflation.

8.3.1 Economic impacts

The results of the studies on royalties for smallholders in relation to ‘eco-forestry’ has been socialised with TFTC who work with both communities and small-scale producers, thus providing them with a better understanding of their income in relation to the benefits of the other parts of the supply chain. This research has been provided to PNGFA who are also endeavouring to provide greater share of the income to local communities but did not have reliable data on which to base decisions.

Extension activities and training at Atzunas and Bopirumpun have provided an awareness of alternative livelihood activities which were not evident before. The focus of the training has been the use of home materials to grow and plant healthy seedlings. Hence, the social impact has been a development of self-efficacy for those people who participated.

The agroforestry systems involving trees and agricultural crops have been analysed in DCF analyses to determine the most likely profitable enterprises for families in the RMV. The average hourly earnings were estimated for each system, which included how the forecasted hourly earnings will change over time. In addition, linear programming models were developed to identify the financially optimal mix of these agroforestry systems subject to labour and land constraints.

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8.3.2 Social impacts

This section overlaps with Section 8.3 on Community Impacts and information is not repeated here.

The current eco-forestry research has identified and documented how and why the current practices are uneconomical for the communities in terms of receiving good value for the timber. Research undertaken with TFTC, FRI and PNGFA and the private millers and processors have identified methods, processes and policies to rectify the situation including identifying more profitable products and timber species and markets.

The project team's research quantified the food and complementary tree-based crops that the target families and individuals are wanting to develop in selected villages. In so doing, the project continues to enhance the knowledge and skills of other families in other areas wanting to improve overall productivity of their land in both the short and long term.

8.3.3 Environmental impacts

The tree based mixed agroforestry systems being developed and implemented will be providing environmental benefits to the large expanses of grasslands in terms of reduced flash flooding, water run-off, soil erosion and reduced incidence of fire damage as 'valuable' clan and family assets are rarely destroyed. The expanded area of forest as 'protected' is expected to create more habitat and a refuge for wildlife as there is a low probability of fire being ignited or allowed to encroach on land that has a value or contains a valuable crop.

The Project has documented that the current smallholder rough-sawn lumber producers that are harvesting in natural forests are generally focused on the 2-4 most profitable tree species. This has led to high grading of the forests harvested by communities, even though the volumes harvested are small. The problem is that the TAs which the smallholders are supposed to obtain are inappropriate, as smallholders are not able to comply with the conditions of the TA (designed for large scale timber harvesting operations). Consequently, landowners mostly ignore it, often with impunity from the PNGFA. The Project in collaboration with the PNGFA has addressed this policy issue in order to avoid degradation of the species diversity and structure in these tropical forests.

It is clear from discussions related directly to the preference study and related to the broader social research, that the planting of timber species by non-clan members is not generally supported by clans. However, gardening by such people is generally accepted; the problem relates to timber. This has large implications for the PNGFA in the RMV in promoting both agroforestry and reforestation using ‘timber’ trees as part of their policy to expand the plantation estate through the program called ‘*Painim Graun, Planim Diwai*’ (Search for land and plant trees) which plans to expand the plantation estate in each Province by at least 1000 ha per year, reaching up to 800,000 in the year 2050.

While the number of trees planted as part of reforestation activities is quite small, increasing the number of interested farmers with relatively small numbers of seedlings offers more promise than a smaller number of farmers with more seedlings. This is important because it demonstrates a level of serious commitment combined with an understandable degree of caution and so any trees planted are likely to be looked after and survive resulting in planted forests that are likely to remain in the future. Farmers are understandably wary of the outcome of what they see as experiments and favour planting trees that do not involve large investments of time with uncertain outcomes.

The collaborative research and training programs were designed to build capacity within FRI and the relevant departments within the PNGFA as well as other non-research partners. This includes the Forest Directorate responsible for community reforestation and the Forest Policy and Planning Directorate in PNGFA to guide their reforestation and rehabilitation program for improving tree cover on clan owned land designated to be forest or in tree-based agriculture.

RAIL as a private sector partner has already benefited by the research collaboration through nursery training which results in higher quality tree seedlings and the resultant improved success of their mixed species plantings required for their high species diversity plantings in their High Conservation Area plantings in the drainage line buffers required under their RSPO obligations. RAIL along with other agricultural companies in the RMV also requires these high species diversity plantings to comply with PNG Environmental Law and subsequent PNG Logging Code of Practice and the National Interpreted HCV Toolkit. The design and species mix are being supported by the mixed species trials at RAIL. The rationale for these plantings is also to protect biodiversity and socio-cultural livelihood of communities bordering the RAIL operations in the RMV. The high species diversity is a specific asset for FLR that incorporates value chain activities, i.e. sustainable practices and/or natural resource restoration, e.g. riparian restoration, soil and biodiversity conservation. This activity provides a model for other agribusinesses that are focusing on reducing the impact of their operations on the social and biophysical environment in which they operate.

8.4 Communication and dissemination activities

A Communications Strategy was developed with the project partners during the Inception workshop on 19 October 2017. A critical part of achieving the project goals is effective communication, including communication between project partners and communication with external parties. As such, there have been challenges associated with effective internal communication between spatially dispersed organisations and between members of partner organisations working on different project activities.

In addition, the project has an increasing number of information briefs and products that are of interest to a broad range of external parties. The Strategy has been divided into 1) internal communications and 2) external communications involving extension publications, and formal publications in journals and conferences. This latter section also involves a 3rd party website Pacific Island Projects (PIP) from PNG which have built and maintained the project web page and provides an opportunity for a wide range of users in PNG. The public web site contains information about the project, details of key contacts and resources that people can download (e.g. reports and extension materials).

The 3rd Asia –Pacific Rainforest summit, 23-25th April 2018, Yogyakarta funded by the Australian Government in collaboration with the Ministry of Environment and Forestry in Indonesia, Indonesia was a good opportunity to present some of the research being undertaken on community forestry and approaches to restoration in ACIAR Projects in PNG and the Philippines. Presentations were made by Dr Ruth Turia –Production Forests and Grahame Applegate in the session on Community Forestry – Policy.

The Asia Pacific Forest Network for Sustainable Forest Management and Rehabilitation (APFNet) had their 10th Anniversary in March 2018. Associated with this event, APFNet sponsored a Conference on Forest Rehabilitation in the Asia-Pacific Region from 26-30 March, 2018 Beijing China. Professor John Herbohn was invited to make a presentation in Session 1-Sharing best practices of forest rehabilitation in different forest ecosystems. In his presentation he outlined the research and lessons learned from the work being undertaken in the ACIAR Projects in PNG and in the Philippines.

USC has held a number of Internal research meetings on the USC campus either associated with prominent visiting scientists such as Dr Horne from ACIAR, or as part of the information research sharing within USC. On two occasions at USC, the ACIAR project in PNG was featured along with other ACIAR funded projects.

The research that was undertaken on the TA process and financial return to smallholders, highlighted the need for improved finance literacy in the communities with whom we worked as well as the research partners and stakeholders within PNGFA. The need for communicating this financial information was also suggested in the Project Midterm Review. There is a wide range of topics that could have been included in a Forest Finance Workshop, as the interests of individuals varied considerably based on their previous knowledge of finance. The topics included; general discussion about how finance is used in forestry; valuation of forests stands; determining which species to select; estimating management costs, determining which silviculture treatments will provide the greatest value to the forest; estimating harvesting costs; general terms used in finance; interest rates; discount rates; compound interest; the time value of money; financial mathematics involving different formulas used in finance; future value; present value; solving for the interest rate; and solving for the number of time periods. The full program which was prepared in consultation with partners became on interest to a number of economists within the PNGFA and other Directorates within the PNGFA. The workshop provided forest-based finance workbooks and spreadsheet templates, so project attendees can communicate this information with forestry smallholders in the future.

9 Conclusions and recommendations

9.1 Conclusions

Timber Authority: The TA was primarily designed for legal logging business entities and was not designed to meet the needs of FROs. FROs generally conduct timber harvests to meet immediate and often urgent cash requirements, resulting in small and irregular harvest volumes. Because of this, FROs typically do not bother applying for a TA. Informal market participants are operating outside the Forestry Act and supporting legislation, and the purview of the PNG Forest Authority. As such, there is no monitoring on harvesting removals, which poses a threat to sustainable timber harvesting practices.

Timber Royalties: The value of the timber royalties being received by FROs in the formal market have been eroded by inflation, thus inadvertently encouraging participation in the informal market where higher prices and more immediate transactions can be received. In 2021, notice was given that the timber royalty rates would be increased, with the previous increase being 13 years prior.

Small-scale timber harvesting: The majority of portable sawmillers in the informal market have received minimal training. As such, the rough-sawn lumber produced is generally of low quality and does not adhere to any lumber grading standards or codes. Therefore, this lumber is less valuable in the domestic market and largely falls below international market standards. FROs and portable saw millers are generally uninformed of the true value of their timber products throughout the value chain, relative to the small-scale wood product manufacturers operating in the informal market. Therefore, it is likely that they are not realizing the full economic potential of their timber and the benefits it can provide to their families and communities.

Gender: While decision-making about land use at the clan level tends to be dominated by men (as land tenure is patrilineal in the RMV), this can be overstated as women do influence decisions in the background. Women are heavily involved in decision-making about crop choices and other aspects of land use in the gardens they manage.

Clans and land use decisions: Clans allocate plots of land to clan members. Clans do not generally act collectively on economic activities on clan land. The activities and who and what is involved are determined at the family level. Clan leadership is usually not inherited or by election. It is usually achieved by prestige and reputation. Sons of leaders may achieve leadership by association with their father’s prestige, but this is not formal inheritance. Technically the leadership is achieved rather than ascribed. There are often several leaders who have authority on the basis of their reputation and social networks. Land use decisions are not usually made by “committees” of clan leaders but informal processes.

Fire: Fire is a major concern in the project area in the RMV. A scoping study was undertaken to improve understanding of the causes of fires. Many fires are lit for purposes of land management or hunting. Some are lit due to conflicts over land. Despite common assumptions (prejudices) relatively few are lit for entertainment. This research was undertaken as preliminary/scoping research and further follow-up research is under discussion. Nathan Wampe from RAIL is currently undertaking a post graduate course at Unitech, Lae, researching the causes and use of fire in RMV and its impacts on RAIL operations.

9.2 Recommendations

From our research findings, we have made the following policy recommendations:

The small-scale timber harvesting sector has the potential to provide better livelihood outcomes and to increase the value of the community owned resource for FROs and local processors. There are a range of actions that can be taken by the PNGFA to improve returns by focusing on the TA process, extension forestry, registration of sawmills and periodic royalty revisions.

Recommendation1: Amend the Forestry Act to allow FROs to conduct small-scale commercial and/or personal timber harvests up to 500 m^3 per annum:

Recommendation 2: Introduce a portable sawmill registration system

Recommendation 3: Increase extension forestry to smallholders

Recommendation 4: Introduce a decentralized, small-scale, timber harvest registration system

Recommendation 5: Continue to monitor, review, and adjust timber royalties in the future

Community-based and family-focused reforestation and agroforestry are necessarily time consuming activities. This applies to the biophysical processes such as species selection and testing as well as community training in seedling production and plantation techniques. Work on the social context is also fundamental. It requires developing a clear understanding of local livelihoods, land tenure, decision-making processes related to land-use and the interests and expectations of various stakeholders regarding project outcomes, well beyond relatively superficial baseline surveys. There is no point in project activities that do not address community needs and expectations. Because the interests of different individuals and groups will differ, stakeholder analysis is essential. Understanding complex communities takes time and must be linked with negotiations within communities and between projects and communities.

Recommendation 6: In implementing community-based and farmer-focused reforestation, including through agroforestry, detailed understanding of the social context is essential and requires patient work with various stakeholders. The social research needs to be combined with negotiations about activities. Agreement by stakeholders cannot be assumed.

Given that the biophysical and social processes involved are necessarily time-consuming and, in the case of social research and negotiations, unpredictable, combining pilot activities and "scaling-up" in a project with a short timeframe (such as five years) is unrealistic.

Recommendation 7: In the case of community-based and/or family-focused reforestation projects which include exploratory pilot activities and scaling up in a short timeframe (such as five years) should be avoided.

Anticipating what the impacts of a community-based reforestation project would be five years after it ends is likely to be entirely speculative. A separate impact assessment five years after the project closes is likely to provide an accurate assessment of biophysical, social and economic/livelihood impacts as well as lessons learned. Such assessments can also identify unexpected or unplanned impacts, both positive and negative.

Recommendation 8: ACIAR should consider a separate impact assessment of this project five years after it closes in order to assess the extent to which project outcomes have persisted or have had wider influence.

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In this section, list references used in the report as well as providing a list of all project publications.

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12 Project Reports in Appendix 1.

Report No.	Authors	Name	Activity No.
01	Thom, M., Wiset, K., Borthwick, F., and Fisher, R (2019).	Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valley. International FLR Conference Manila February 2019	1.1, 2.3
02	R. Fisher	Social science research training No.1 (Part 1 & 2).	1.1
03	R. Fisher.	Social science research training No.2	1.1
04	Kagl, R., Wampe, N., Thom, M., and Fisher, R.	Preferences for family-based agroforestry in the Ramu-Markham Valley	1.1
05	M. Scudder, N. Wampe & Melinda Thom	Bio-economic models for tree-based livelihood systems	1.2
06	Scudder, M., Wampe, N., Waviki, Z., Applegate, G., and Herbohn, J	Small holder cocoa agroforestry systems; is increased yield worth the labour and capital inputs? *Agricultural Systems* 196	1.2
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08	Scudder, M.	Umi Agroforestry Demonstration	1.2
09	Z, Waviki	Variable Spacing Trial Commencement Report	1.3
10	W. Andusa	Variable Spacing Trial Commencement Report	1.3
11	M. Scudder	On Line Report on Species Trial Analysis	1.3
11a	N. Gregorio	Establishing Feld Trials in PNG	1.3
12	N. Wampe	Commencement Report – Umi Plot	1.4
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15	M.Scudder	Umi Agroforestry Brochure	1.4
16	C. Cingle	Commencement Report Umi	1.4
17	V. Andrew	Report on Daulo Training	1.4
18	C. Single,	Nursery training at Atzunas community	1.4
19	N. Gregorio	Nursery Report	1.5
20	N. Wampe	Commencement Report Mixed Species Trial -RAIL	1.5
21	W. Andusa	Commencement Report – Mixed Species - Goroka	1.5
22	H. Morte	Commencement Report – Variable Spacing Trial Setun	1.6
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25	Jeffrey, G., Morte, H., Applegate, G., Yelu, W., and Golman, M.	Tree species selection: One of the components for successful FLR in PNG Conference abstract	1.6
26	Wiset, K., Baynes, J., and Applegate, G.	Community-based Landscape Scale Reforestation Initiatives in Asia-Pacific	2.1
27	M. Scudder	Brochure on Project	2.1
28	Wampe, N., Fisher, R., Applegate, G. and Baynes, J	Anthropogenic Fires in the Ramu- Markham Valley	2.1

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33	M. Thom, K. Wiset, F. Borthwick. And R. Fisher	Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valleys	2.3
34	N. Gregorio	Identifying Mother trees in Biodiversity Buffer Zones for Reforestation	2.4
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40	Scudder, M.	Small-scale Forest Management Planning & RIL Online Workshop - scheduled for September 2022	3.4
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47	Scudder, M.	Introduction to Forest Finance – Online Workshop Report	3.6
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Appendix 1.

Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valley[1]

Melinda Thom, Kanchana Wiset, Fiona Borthwick and Robert Fisher

Abstract
Efforts to implement FLR in the Ramu-Markham Valley (RMV) have increasingly focused on family or small group based activities, incorporating agroforestry. Gender issues are crucial in these activities both for practical and equity reasons. The practical reason is that even though both men and women have a key role in any agricultural activity, women provide much of the labour on a daily basis. Interventions will only be successful if women support activities, benefit from them both in the short and long term and are willing and able to provide labour. Equity is important because changes to gardening and related activities impose costs on women, both in the form of increasing labour and changes to the availability of food and forest products and the distribution of benefits from these. Society in the RMV tends to be heavily male-dominated and this is reflected in decision-making including decisions about use of resources. Nevertheless, the domination is not absolute and understanding opportunities for greater involvement of women in agriculture and agroforestry requires nuanced understanding of the women's roles and activities. This report presents results of action research by Melinda Thom, into the relationship between gender, women's labour and economic activities in the RMV, paying attention to resource rights and decision-making about resource use and benefit sharing. The work is complemented by findings of research carried out by Kanchana Wiset as part of her PhD studies and an intern's report by Émilie Tremblay. The report also provides recommendations relating to ways to incorporate gender into project activities as a cross–cutting theme.

Introduction

The Ramu-Markham Valley (RMV) contains two rivers flowing in opposite directions – the Markham to the south-east and the Ramu to the north-west. The watersheds of the two rivers are separated by modest watershed boundaries. A significant portion of the valley floor consists mainly of grasslands, with forests mainly on the slopes of mountain ranges to the south and north. The grasslands are anthropogenic and have been a critical feature for around three thousand years.

In recent years Ramu Agri Industries Limited (RAIL), in partnerships with a series of projects supported by ACIAR, have been engaged in efforts to reforest areas of the

[1] This report is a revised and expanded version of a paper presented by Melinda Thom at the International Conference Forest and Landscape Restoration: Making it happen. 25-27 February, 2019, New World Hotel, Makati (Manila). It is intended that the report will be further developed for publication after the formal end of the project.

grasslands. The ACIAR project currently working with RAIL is “Enabling Community Forestry in Papua New Guinea”. In earlier incarnations the emphasis was on working with clans to establish tree plantations. In the current project the emphasis has been on working with small groups or individual families to establish agroforestry plots. These family-based agroforestry plots need to be planned in collaboration with clans which ultimately own the land which clan members use individually for gardening and other purposes. Tree plantations and agroforestry plots are, to some extent, novel land uses and such innovations require clan agreement.

As much of the labour for gardening (which is a major element of agroforestry) is provided by women, activities will only be successful if women support activities. In addition to this practical reason for understanding gender and land use issues, gender equity issues have human rights implications. They are important because land use change affects the labour demands on women, so changes may seriously disadvantage them.

While, as the literature review will show, there is a body of literature on gender in agriculture. However, the Melanesian literature sometimes overgeneralises about aspects of gender, particularly on the gender division of labour. Even within regions and cultural groups, behaviour does not always fit abstract statements about what happens, and there are significant differences between regions. There is very little literature on agriculture, forestry and gender in the RMV.

This report has been written because experiences during the implementation of the RAIL/ACIAR project have highlighted the problems with oversimplified assumptions about the role of gender in agroforestry and forestry. The aim of the paper on which the report is based, was to present a preliminary account to what has been learned through such experiences and to reflect upon the lessons that can be drawn from them and implications for future activities.

The paper draws on the experience of staff in the joint project, PhD research (Wiset et al., 2022) and an intern’s report (Tremblay 2017). It also draws on internal project documents supplemented by published literature where relevant. Further research would be useful, but we believe that the material presented here advances the limited material available on the topic in the RMV.

Literature review

Gender studies in PNG occur in the context of significant gender inequalities between men and women. These issues are well documented in country assessments particularly the UNDPs Human Development Index (UNDP 2017). PNG scored a ‘Gender Inequality Index’ value of 0.741, giving it a ranking of 159 out of 160 countries (low ranking shows high gender inequality). This ranking is based on the low parliamentary representation of women, low secondary educational level of women compared to men, high maternal mortality rate. Female participation in the labour market is very close to male participation (69% to 70.8%) (UNDP 2017).

According to Tremblay (2017)

> PNG culture is described as discriminating against women in various ways, which is often used as an excuse not to challenge customary practices. A new financial agreement [between the European Union and the Pacific Islands Forum Secretariat] was signed in September 2017 in order to address gender inequalities and violence against women and girls in the Pacific, further indicating how these are current concerns..

Gender inequalities in PNG are described as systemic (World Bank 2012): women suffer a range of gender specific inequalities such as domestic violence, lack of access to education and health care, lack of political representation, and in many instances lack of voice in decision making from the community to the national level. Male gender inequalities are less evident in the literature but never the less must be considered in terms of increased exposure to risk, or lack of skills in some domestic areas due to constructed views of masculinity. Beyond male/female gender inequalities, consideration of non-normative issues in relation to gender is extremely limited in the PNG context, – to the point of almost complete absence. This is largely due to the legal restrictions non heteronormative individuals face. Transgender, inter-gender or queer literature is in the most part non-existent:

> Compared to many other Pacific Island societies, there is little scholarship on modern non-heteronormativity's in PNG. Nor are there any conspicuously visible and identifiable groups of non-heteronormative people in mainstream PNG life, as there are farther east in the region. (Alexeyeff et al 2014)

One aspect of gender dynamics that emerges as vital to include is that of intersectionality, in that each individual has multiple identities within a household and community that influence their experience and vulnerability (Colfer et al, 2018). This is of particular importance in a location such as RMV because of the diversity represented in these valleys. Diversity of clans, social norms, intermarriage, and power among both men and women.

Gender in agriculture and forestry in PNG

Female participation in the labour market is 69%, male is 70.8%, suggesting a somewhat equal participation in the labour market as a whole (UNDP 2017). Allen (2009), in a review of agriculture and gender in PNG, estimated that half of all agricultural labour is carried out by women and we do not challenge this estimate. There is often an assumption that women will carry out the maintenance of gardens, and men will focus on cash crops or forest crops such as cacao, coffee and timber trees, as well as labour such as forest clearing. Allen suggests that male knowledge about gardening is more limited than women's knowledge.

There is literature on gender in the RMV, but there is not much on gender in agriculture or forestry, apart from literature arguing for the importance of women in agriculture. There is little if any literature on the impacts of changed land use practices on women. Interestingly some of the studies that focus specifically on the RMV (more often on the upper Markham) make little or no reference to gender. Even Holzknecht (1974, 2014), who has written perceptively about the social organisation and agriculture, makes little explicit reference to gender issues. Read's (1950) very early account of social organisation in the Upper Markham Valley also says little about gender.

Most studies discuss gender divisions in terms of: 1. The household, where women carry out cooking, cleaning and the majority of childcare; 2. Gardening, where men have defined roles in terms of clearing, some heavy jobs (need ref) as well as some maintenance, women do much of the weeding, watering, and harvesting; and 3. Communities, where men have the majority of decision making roles and interacting with neighbouring communities. Assumptions are made about head of household always being male, but there are many instances where a woman is a head of the household.

Despite the above simplification of gender roles, empirical studies show, it is important not to make generalisations about the experiences of genders in PNG, the roles gender places in day to day life and the relationship between formal legal perspectives, local norms, and the individual lived experience. This caution is highlighted by Allen (2009). While the general conclusion is that most of the work done in gardens is carried out by women, this is not true in all contexts, clans, communities or across timescales. Having said this, this literature review highlights some of the key assumptions in relation to gender in PNG, and in relation to agro-forestry and forest landscape regeneration. In our analysis, we show where some of this work can be challenged.

Experiences of gender in agriculture and forestry in the Ramu-Markham Valley.

Land Tenure

Ninety-seven percent land in PNG is customarily owned by clans. Land based decisions are based on the magnitude of intended land use. If decisions are to be made on a larger landscape the clan will have an immense deliberation on this matter. If smaller landscape decisions are to be made in terms of the surrounding garden areas or within the vicinity of family homes then it is an individual or family based decision making process. These decisions are mostly dominated by the male members of the clan and or family. This is because land use rights are inherited through the male child in a family. For example, in the Markham Valley, a portion of land referred to as *buafump* is a land that would have clear use rights. *Buafump*, in the local dialect, means that where the ancestors have planted, one should remain on that land. An informant stated that women do have user rights until when they are married and move to their husbands' *buafump*. Widows can return back to the village and still have rights over the *buafump*. These scenarios are dependent on the woman's relationships with in-laws and brothers, leading them to be reliant on familial networks.

There are interesting cases of women who have actually gone against the assumed norms of a male dominated society. For example, in one village in the RMV, a widow who returned to her village is recognized as a prominent leader, church leader and a politician. She also is observed to have use rights over land within her clan. It was also observed that because of her status in the village, she would meaningfully participate in discussions around land usage and at times can influence decisions made. This case shows that gender norms are complex and dynamic in this region. However, it must be noted that her status is strongly linked to the status of her father which gives her certain exemptions from local norms. Her sister also married outside has moved back to the village with her sons and husband and are using land that their mother has rights over. This is a reflection that regardless of land being clan owned and use decided by men man, women do have rights that can be passed down to their sons. The implications of such can result in conflicts in benefit sharing in future projects that have economic benefits as such benefits are distributed among the male lineage.

Another example is the case of a local woman who had returned to her home village with her husband who is from another province. They have both been given user rights to plant trees for sale and planted in a larger area than expected. This has brought about conflicts within the family. The case clearly shows that customary laws are not always clearly defined or strictly enforced. They can be amended to fit situations. This can reflect the importance of proper negotiations before projects are implemented with impacts and benefits clearly explained and understood.

It is also observed that in most cases, regardless of the user rights, most discussions and decisions are made on behalf of the female with user rights. Again, her relationship with her male relatives will determine the level to which she is party to the decision-making process.

Division of Labour

In most parts of PNG, men and women work together in their gardens, sharing almost all of the labour and the contribution of knowledge and skills (Allen, 2009). Usually with the help of other family members, the male members would take on the heavier tasks such as land preparation while women would take on the lighter tasks such as planting, daily upkeep and harvest. The management of the garden through to harvesting in the RMV is usually done by women.

Within households women in the RMV take on the majority of domestic tasks such as childcare, cooking, cleaning, again men are mainly in charge of heavy labor such as house building and maintenance as well as negotiating with neighbors.

Even though women are willing to work on agro–forestry activities, their full participation is dependent on the scale of the activity.

As Tremblay (2017) has reported:

> Few suggested that an agroforestry activity on a smaller scale can be integrated into their daily chores. A larger scale agroforestry activity will increase their workload where they will be forced to prioritize thus this activity can be entirely neglected.

Generally, women are expected to be able to ensure that the daily needs of their household are met. Should extra workload be seen to make her not to meet her family's needs on a daily basis, a woman can be seen as a wife not capable of providing for and looking after her immediate family.

Gender roles and responsibilities are quite distinctive and both men and women are expected to ensure that they do their roles accordingly.

Decision Making

Women's participation in decision making can vary depending on the various issues. As stated above, at the family level, though the decision would be made by the male members of the family, a woman can easily influence the decision as she would be dealing with immediate members of her family. This is different at the clan level where extended male members of the family and clan decide. Women sometimes believe to participate in the decision making by agreeing to the decisions made but that can either be a genuine agreement if she has involved in parts of the process or it can also be that she is required to agree regardless of her understanding basing her trust that the decisions are in the best interest of her family or clan.

Lack of access to resources, information and knowledge can limit women's capacity to take part in the decision either at the clan level or family level. Therefore, it is imperative to ensure that women participate meaningfully in entry meetings of agro-forestry projects.

It is important to note that women's role in decision-making at clan level and household level are quite different. This issue is explored in some detail in Wiset et al. 2022. In the RMV clans rarely engage in economic activities (such as gardening and food production). Their main decision-making role relates to allocating land to clan members. The clan members are male as clan membership is based on patrilineal kinship. Decision-making about gardening and food production are made at the household level.

It was observed that women members of an executive committee of an Incorporated Land Group (ILG), which may be formed to assist clans to negotiate with businesses, do not necessarily see themselves as active members of the committee. For example, when attending and observing a certain ILG meeting, women representatives were observed to be vocal in the meeting but more so speaking as a general member of the ILG rather than a member of the executive committee. We suggest that this can be a result of lack of consultation by male members of the committee with the women and that decisions reached during executive meetings were done without the knowledge and participation of women. Having women as executive members of the committee can sometimes only be to ensure that certain requirements of an institution are met. On a positive note, it gives the women power to ensure that whoever they vote to represent them in such meetings can be able to voice their concern.

Other examples include women who are involved in smallholder blocks of Oil Palm where portions of land are divided amongst all the children. It is observed in meetings with smallholders that women who own smallholder blocks are outspoken. The can be a result of them being empowered enough to speak with other male smallholders. Even though the percentage is very low compared to male smallholders, there are a number of women own smallholder oil palm blocks.

It can be noted that education plays an important role in empowering women enough to be able to participate in the decision-making process.

It is important to note that formal decision-making power is not the only way women can influence land-use decision-making. A plan was negotiated by the project and a clan member (in project phase 1) for an agroforestry plot. The plot was supposed to be one hectare in area. When the plot was established the area was much smaller as the women who did the work decided they were not able to carry out so much extra labour. The women exercised their power simply by deciding what work to do ("*voting with their feet*"). This seems to have been accepted by the male land owner. This illustrates that women can exercise significant "informal" power, simply by ignoring or modifying more formal decisions.

Women's preferences regarding trees and services from trees in agroforesty

An internal project report (Kagl et al, 2018) examined the preferences of women and men in two villages for services from family-based agroforestry. Although the results are not comprehensive, there were some useful general findings. Overall:

> Both male and female members described their needs and benefits to be derived from the different trees and, importantly, preferred local species. They also expressed interest in mixed species. The women requested fruit and medicinal trees for marketing and family consumption. The most repeated need during the interviews was for both male and female was for the trees to be used for house construction. Other needs included and highlighted were medicinal plants, fruits, nuts and fuel (firewood & charcoal).

Some findings were particularly relevant to labour demands on women:

- “Women (from both landscapes) expressed the importance of plots not being too large as that would lead to increased work for them.”
- “Women also expressed a strong preference for plots to be located close to their houses.”

Similarly, Wiset et al. (2022) found that women tend to have different preferences from those of men regardingplanting patterns, including a preference for planting trees near their houses and in home gardens. Their interests tended to be more focused on crops, including trees, for domestic use rather than for sale.

Exposure to Risks and hazards

Agro-forestry activities such as the creation of tree nurseries or new plantations in the RMV may expose men and women to risks and hazards and some have a gender bias. For women, a nursery, or planation far from the garden, or a large plantation would increase workloads and the need to carry water. Even after activities have been negotiated and initiated, issues may emerge. In the case of one village, agreements were made to establish agroforestry on a one hectare plot. However, eventually much smaller plots were prepared, because the labour demands on women preparing the larger plots were prohibitive.

If the nursery or planation is on disputed land or on boundary land this could increase exposure to violence. For men, activities on a separate plot of land, on land where ownership or boundaries are unclear or in dispute could expose them to higher risks of theft, violence and other forms of conflict such as arson.

Conclusions and implications

The above discussion of gender aspects of agriculture and forestry shows clearly that some assumptions made about the roles of women have been oversimplified. Women’s roles and potential input in agroforestry needs to be more nuanced than is typically the case. For example:

- Although decision-making about land use is typically assumed to be male-dominated. There are situations where women do make decisions, particularly in relation to the gardens near their houses and home gardens..

- Women's rights to land for productive purposes are not always simply a result of their status as wives of men with rights. Some women do use land in their own name, including for non-subsistence purposes. In addition, women who have married out of their village who return with their husbands may also have access to land. Their husbands, although outsiders, may also have access to land.

These apparently minor differences highlight the way that common generalisations about gender issues may be inaccurate. They show just how nuanced the understanding of gender has to be in planning and implementing agroforestry activities. That is a clear lesson from this research.

This paper starts from the premise that gender (especially as it refers to women) is essential for FLR and agroforestry interventions, both for human rights reasons and for practical reasons – if women do not support new land use practices they will often fail, especially as their labour is essential.

Finally, it is worth mentioning reservations about the extent to which external actors, organisations like RAIL or bilateral projects, should attempt to radically change gender relationships in PNG. This is usually not appropriate or practical. However, such reservations do not justify ignoring the gender implications of interventions. The absolute minimum standard is that women's lives should not be made worse as a result of interventions. More positively outcomes should make their lives better in ways that reflect what they see as improvements.[2]

Implications and recommendations

From the point of view of future practice in FLR and agroforestry programs there are several important implications:

- *It is essential to talk to women before anything is done in order to assess their preferences. Discussion should not be limited to discussions with men who say they want to plant trees or gardens, where they want to plant them or what species should be planted. Implication of land use changes need to be clearly understood and agreement negotiated.*

  Importantly, failing to consider women's preferences before agroforestry or reforestation acivities commence may lead to serious negative impacts on their labour.

- *Consultation should not take place just at the planning/negotiation stage. Issues emerge as activities proceed. There is thus a need for continual monitoring.*

[2] RAIL has obligations to take gender seriously under the requirements for Roundtable on Sustainable Palm Oil (RSPO) certification and Rainforest Alliance Certification.

- *It is essential to be aware of preferences commonly expressed by women, such as the need for plots to be close to the village.*

  Again, ignoring these preferences may have negative impacts on women's labour.

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Enabling Community Forestry in Papua New Guinea

Social Science Training Workshop

22-26 January 2018

RAIL Guesthouse
Ramu

Robert Fisher
Senior Research Fellow
Tropical Forests and People Research Centre
University of the Sunshine Coast

PARTICIPANTS

Facilitator:	Bob Fisher University of the Sunshine Coast
Melinda Thom	RAIL, Community Engagement Manager
Regina Kagl	Project Sociologist (RAIL)
Nathan Wampe	Forestry Officer (Newly appointed at RAIL)
Simon Wanga	RAIL
Will Unsworth	Sustainability Manager (RAIL) and USC PhD student (Will left on the morning of Day 3)
Vincianna Andrew	PNGFA, Eastern Highlands Province
June Mandawali	PNG Forest Research Institute
Haydrian Morte	PNG Forest Research Institute
Mywish Miori	RAIL Intern
Kanchana Wiset	PhD student USC (participant and assistant facilitator)
Issac Alex	RAIL Joined Day 3 to assist with practice exercise and continued participating.

There were a total of 11 participants; 6 female, 5 male (of whom 5 women and 5 men were from PNG partners)

Jack Baynes	USC – additional resource person joined for days 4 and 5

INTRODUCTION

This workshop was organised for PNG-based researchers associated with the ACIAR funded project. The aims were to

- Present an overview of the social science related activities of the project (for Objectives 1 and 2) and an overview of relevant concepts;
- Train the participants in social science methods <u>relevant to the project</u>;

- Develop an initial plan for applying the methods in the field during project activities.

There were several factors that affected the underlying approach taken during the workshop. The main point is that the participants, with one or two exceptions, were trained in forestry, environmental science or other biological sciences and had little training in social sciences. On the other hand, several participants had been involved in phase 1 of the ACIAR project[1] and of these some had attended a similar workshop held in February 2014 (also facilitated by Bob Fisher). Thus, participants in the 2018 workshop were a mixture of people with very limited experience or training in social sciences and people who had relevant field experience and some initial training.

In this context, and given that it is no more possible to train people to become social scientists in a few days than foresters or agriculturalists can be trained in a few days, the workshop aimed to present a broad overview of methods relevant to project activities and to enable participants to reflect on and share their relevant experiences. Relevant experiences included experiences from Phase 1. Importantly, participants were able to use their own lived and rich knowledge of PNG society to inform discussion.

Given the available time, the workshop focused on concepts and methodology relevant to project objectives and activities rather than attempting a broader introduction.

The focus was, therefore, on qualitative methods. Emphasis was placed on interviewing techniques and skills. This included a classroom practice exercise and a field practice exercise, interviewing RAIL staff on attitudes to the RAIL's mosquito eradication program.

There was also a focus on action research and action learning, as this is central to the project as a learning project, developing new approaches and techniques rather than a project that implements established techniques and approaches. In terns of social research, the project requires an ongoing process of action research in which field staff work with communities to plan activities, implement them and reflect on outcomes before moving to new cycles of planning, acting and reflection. In addition to these ongoing activities there is scope to implement a small number of more focused studies.

A learning approach was built into workshop planning. The workshop depended on reflection by participants, on their relevant experiences, current roles and presented materials.

Some key concepts were presented at the workshop:

- The concepts of landscape and Forest Landscape Restoration;

- Stakeholders and stakeholder analysis;

[1] Enhancing the implementation of community forestry approaches in Papua New Guinea (FST/2011/057)

- The relevance of gender;
- Action research.

PREPARATION FOR THE WORKSHOP

A set of readings was circulated to participants prior to the workshop. These were circulated by email. Issues with email access limited the number of readings and the size of files. The list of readings in in Appendix 1.[2]

DAY 1[3]

After a general introduction and outline of the workshop structure and process, the workshop began with presentations by two participants on their experiences with socials science research, based on their experiences in Phase 1.

June Mandawali (PNG Forest Research Institute)

In addition to her specific role at the FRI related to field trials, June was involved in field work with communities at Ramu in Phase 1, collaborating with RAIL staff. June presented a powerpoint presentation entitled “Role of PNG Forest Research Institute in Research”.

She explained that the FRI’s main role is “To provide [the] scientific basis for the management of PNG’s Forests”. The main research areas are: Plantation forestry, Natural Forests, Forest Products, Forest Biology. There has been little work done in social forestry, apart from landowner engagement. There have been some studies, but it is hard to access data. Regarding previous forestry extension programs, the records are not good.

Melinda Thom (RAIL, Community Engagement Manager)

Melinda was heavily involved in the fieldwork with communities in Phase 1. She explained RAIL’s involvement in the project. RAIL already has an extensive program in community engagement, which involves planning and making agreements with communities about land use. The engagement with the project was somewhat different from the normal role of RAIL with communities, as efforts were made to make it clear to communities what activities RAIL was involved with as part of its partnership with the project. However, in practice people tended to think of the ACIAR project as a RAIL project rather than a separate project which RAIL was helping with.

[2] Kanchana Wiset assisted the facilitator in identifying and selecting the readings.
[3] This report contains a summary of the steps taken during the workshop, but there is limited detail on discussions as the role of facilitator does not allow time for detailed note-taking.

Explanatory comment (added by facilitator): This raised issues about the risk that project activities will raise expectations that RAIL will provide resources to communities. It also raises potential issues in terms of the ethical requirements for the project (as an activity by an Australian university) that communities be clearly informed about what the project is about and their right to participate or not in the research.

In discussion a participant asked Melinda what the added value of involvement in the project is for RAIL. Melinda replied that RAIL wants to build relationships with communities and this is not just about RAIL's business.

Will Unsworth added that RAIL operates under environmental requirements as a responsible palm oil producer (under RSPO). RAIL has always had a forestry program and the ACIAR project contributes to that. The community decision-making processes that go into community forestry are the same as those involved in negotiations involving RAIL's normal business.

The Project: Information and Overview (Bob Fisher)

Bob presented a powerpoint presentation about the project objectives and activities, according to the project document. The presentation highlighted details about the specific social science research that workshop participants would be involved in.

He explained that the approach in Phase 2 is a new approach compared to the approach is Phase 1, which was largely about working with community groups (clans/sub-clans) to establish community forests (ie based on collective action). In this Phase the shift is to a landscape approach and working with families/small groups to develop agroforestry plots in landscapes.

He stressed that involving the wider community is still going to be the main challenge for fieldwork with communities as landowner clans have to agree to the use of lands for agroforestry.

In discussion, Melinda reminded everyone of the risk of raising expectations when communities are approached.

International experiences in community forestry: social science perspectives (Bob)

Bob presented a powerpoint on the background to community forestry, mainly in Asia, focusing on social science aspects. The presentation provided examples from a number of countries, including, Nepal, India and Thailand. It also introduced some key concepts: institution, organisation, participation.

An important message from the presentation is the need to understand the context within which community forestry occurs – a major reason why social science is necessary.

The key question posed at the end of the presentation was: How is PNG different?

One factor is the nature of tenure in PNG, where it is legal customary tenure (mostly clan-based). In most of the other countries used as examples the forests are owned by the state.

One suggestion was that PNG is different because land is privately owned. There was some debate about whether this is genuine private ownership or a case of individual rights to clan land. There seemed to be a consensus that land in the Ramu-Markham Valley (RMV) cannot be described as private. (On the other hand it is less clear in parts of the highlands). This discussion highlights the importance of being very clear about terminology. Tenure can be described as private or common, but understanding tenure requires clear discussion of what the actual rights involved are and how rights are balanced. This is an important issue for social science and land use for PNG.

Another point is that community leadership in PNG is not formal, but customary and based on prestige. On the other hand, PNG is similar to other cases where government regulations impose limits on what forest products communities can sell.

An important challenge for the project will be providing benefits for families as some level of agreement is needed from clans.

Will Unsworth commented that the project assumes that people will benefit from trees, and asked “what if they don’t want them?” Nobody has asked for trees or for the ACIAR project.

Presentation on PhD Project (Will Unsworth)

Will presented a powerpoint on his PhD research. No details are included here as this work is not yet published and is part of an ongoing project.

DAY 2

Film: “Second Nature”

This is a classic documentary film (1996) about forests in Guinea’s transition zone – between the desert and savanna. Colonial administrators traditionally believed that the local people had destroyed the forest. Two British anthropologists and a local historian were studying the process, accepting that the common view was correct. However, they realised that the common belief was wrong and that, in fact, the area was traditionally savanna and the local people were actually establishing new forests around their villages. This information came from local oral history and was confirmed by aerial photos which showed that forest cover followed villages as new villages were established.

The film conveyed several messages:

- It illustrated how participant observation is practiced – understanding a society by participating in activities and learning from the people;

- It illustrated the idea of checking qualitative findings by triangulating them with other methods – in this case confirming oral history and ethnographic observation by reference to sets of aerial photos;
- It showed how fire can be used for constructive land management (clearly relevant to PNG);
- It provided a warning against holding popular assumptions which bias your understanding of social/environmental interactions.

Conservation Landscapes (Bob)

Bob presented a powerpoint presentation on “Cconservation landscapes: Whose landscape? Whose trade-off?” This was originally presented at a meeting in Morges, Switzerland in October 2001 by Stewart Maginnis, Bill Jackson and Nigel Dudley of IUCN.

The presentation stressed that landscape boundaries are flexible and socially constructed. Landscape boundaries can change as new issues emerge. A key idea is that a landscape consists of parts with different land uses and that this requires these different land uses to be traded off against each other. In other words they are negotiated (socially constructed). It is important to include groups that impact on each other in negotiations.

Discussions focused on how these ideas might relate to PNG, especially as the project is committed to a landscape approach. Effectively the discussion problematised the concept.

How could the project identify a landscape? What would the boundaries be? It could use clan territories as landscapes, but how could it deal with the fact that clan members may live outside their clan’s territory? Even if a clan’s territory is selected as the landscape, other clans with other territories may also impact in a clan’s territory, so landscapes need to be larger.

A decision on landscape boundaries needs to be pragmatic. Participation of all stakeholders may be impractical. The problem is somehow circular: we need to know the stakeholders in order to define a landscape.

We may have to add new stakeholders as necessary and expand boundaries as necessary.

Models for engaging communities in Forest Landscape Restoration for livelihood improvement in Asia Pacific: Case Studies in the Philippines and Papua New Guinea (Kanchana)

Kanchana's presentation dealt with conceptual aspects of FLR in relation to her PhD studies (with case studies in both PNG and the Philippines). She asked workshop participants whether they thought the research would be practical. One participant asked what she would compare.

The presentation was useful in presenting the theoretical background and history of the FLR concept.

Stakeholders and stakeholder analysis (Bob)

In this powerpoint presentation Bob outlined the concept of stakeholders, which he defined as being of two types:

- Different categories of people who are affected by an NRM decision;

- Different categories of people who can affect the outcomes of NRM.

If we are trying to understand decision-making and negotiations we need to know who wants what. In stakeholder analysis we aim to identifying all of the people who want particular outcomes and look for areas of compromise and conflict. It's important to understand that different stakeholders have different levels of power over decisions.

This presentation is at Appendix 2.

The following discussion focused on an exercise identifying stakeholders.

The group identified the following stakeholders:
- Churches
- Local government
- CBOs
- PNGFA
- FRI
- District officials.

But so far these were all external stakeholders. What about internal stakeholders (within communities)? Suggestions were:
- Village magistrates
- Landowners (suggestion "break that down")
- Clans
- Village leaders
- Other clans
- Leaders (June said "if you have a good leader you will probably have a good outcome).

Gender landscape and agroforestry matters (Regina Kagl)

The powerpoint presentation is in Appendix 3.

Introduction to Social Science Methods (Bob)

This was presented as a powerpoint (Appendix 4).

The presentation focused on various qualitative methods, when these are useful and how they can be used.

The main methods identified were:

- Dialogue/semi-structured interviews;
- Group interviews and focus groups;
- Participant observation.

Role plays: Practicing interviews

The presentation on social science methods was followed by a session on practicing interviews. This was a lengthy exercise using role plays. Four scenarios were prepared and an interviewer and interviewee were selected for each scenario. In one case there were two interviewers and one interviewee (due to the uneven number of participants).

Each pair was given an interview to prepare and then perform in front of the rest of the class, who then provided feedback on interviewing technique. The interviewee was given a piece of paper with her/his role and notes on the role. The interviewee was given instructions on what the particular interviewer was to explore.

Appendix 5 provides the scenario briefs and guides for interviewers.

After each pair performed the role play, comments were given as feedback. Details of feedback are not given here, but the point was that it was all positive and useful. Participants learned from each others' experience. One example of a comment was drawing attention to a leading question.

DAY 3

Preparation for "field exercise"

In order to avoid an artificial round of field visits as an exercise, we decided to carry out a small exercise on-site at RAIL to assist with RAIL's mosquito control program. This avoided the potential problem of field visits to communities which had the risk of raising expectations.

The background to the mosquito control program is that the RAIL community (staff and families living in RAIL accommodation) are subject to a high incidence of malaria. The unit managing the mosquito eradication program needs information about what people feel about malaria and what their needs are in terms of focusing the program. This provided an opportunity for a simple exercise in interviewing staff and families to obtain such information.

Isaac Alex, who runs the program briefed the participants who then developed questions based on themes identified based on Isaac's presentation. (Themes identified are in Figure 1.) The participants worked in pairs to prepare questions and their approach to interviews and then reported back for feedback, modifying their approach accordingly.

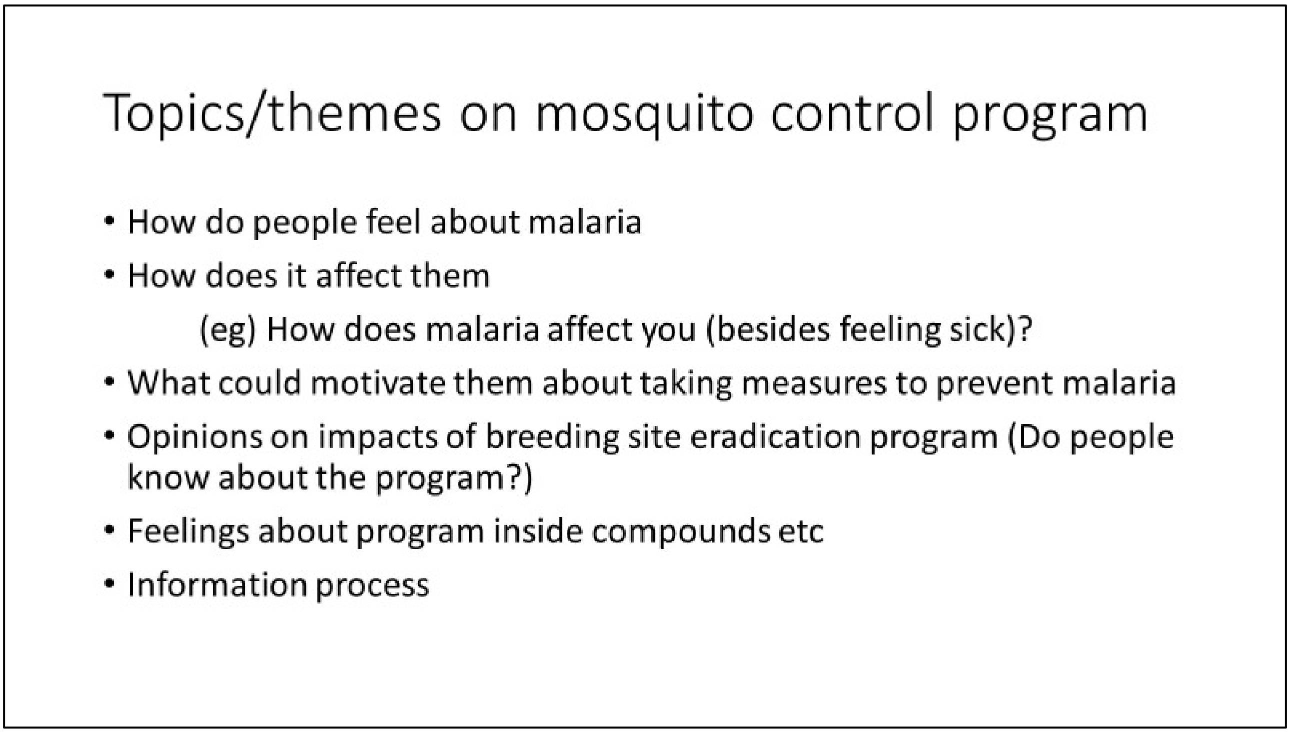


Figure 1: Themes identified for interviews (practice exercise)

Finally, participants compiled a slide with principles for good interview based on experience in the role plays on Day 2 and discussions earlier on Day 3.

These interview techniques and principles were:

- Make sure you explain why you are doing the interviews
- Get to know people before you begin the formal interview
- Understand local customs about how to interact with people (eg looking too directly)
- Open questions get more information than closed questions
- Probe and follow up
- Interviewee should be doing most of the talking
- Be concrete – not too abstract
- Relate questions to something people understand
- Avoid leading questions

- Avoid being judgemental
- Follow local practice about recording interviews (both on sound recorders and in notebooks)
- Maintain confidentiality in notes and reports
- Check that you have understood answers correctly.

It's important to recognise that these principles were developed from group reflections on practice exercises and group work. This dependence on reflections was an organising principle for the workshop.

Day 3 - afternoon

Action Research (Bob)

The presentation on action research is at Appendix 6.

The presentation provided an introduction and overview of action research. It discussed two case studies: one was on dryland rice farming in Cambodia; the second was on action research carried out in Goilala District in PNG.

Action research is a cyclical and exploratory process. It is a suitable approach when:

- A problem being investigated is very complex
- People don't know where to start in solving a problem, or don't know the next step
- Change involves people with differing perspectives when there is need for a common vision
- The situation or context is changing

All of these conditions will apply in the case of the project's research with communities.

Tools and techniques (Bob)

Tools and techniques are specific methods used to obtain data in the context of methodology, which is the broad approach. For the field research that will occur in the project a number of tools used in Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) are useful. Useful tools are:

- Interviews and observation;
- Sketch maps including forest land use maps;
- Transects/transect walks;

- Time lines (indicating changed land use over; village history etc);
- Seasonal calendars (activities occurring during different seasons);
- Market chain analysis.

There was no time to attempt practice all of these tools, so a practice session on sketch mapping was carried out. Three groups were formed and these each prepared and briefly presented a sketch map on butchers paper. The three groups each prepared a sketch map on one of the following: the RAIL compound where malaria breeds; Sankiang village; Lapegu forestry station.

Video

A video made by the then Nepal-Australia Forestry project was shown. *Sadupayog: Forest Management for People* (1989) is a training film made for Nepal Department of Forest staff about the community forestry program and the skills needed to work with communities.

DAY 4

Interviews on Mosquito Eradication Program

The interviewing exercise was carried out by five pairs of participants. Each pair had two interviews: one with RAIL staff and one with dependents. This exercise took all morning.

After lunch presentations were prepared by each of the pairs. The presentations were to be organised according to the themes listed in Figure 1 with a conclusion on the implications of the findings (what needs to be done).

In order to respect confidentiality, the presentations are not provided in this workshop report. However, a few key results are listed below:

- Many interviewees had little or no knowledge of the MEP;
- Even when people had some knowledge, they often didn't know details;
- Some people were reluctant to take malaria medication as they believe it makes the body weak;

- Reports made suggestions for improving the program, particularly in terms of communicating with employees and dependents.

DAY 5

Conclusion of practice interview exercise

Participants were asked to prepare reports on the exercise based on the work of each pair and to send these to Isaac to assist in future activities in malaria eradication.

Bob pointed out that the exercise covers all phases of qualitative research:

- Problem/theme identification;
- Planning methodology (when, who to interview, team members, questions, steps);
- The research must be carefully prepared, even if it is informal;
- Implementation;
- Reflections for the survey/interview report.

He emphasised that reports on interviews/surveys should include data and analysis/interpretation. These elements should be kept separate.

Reflecting on the interview, Isaac stressed the importance of making informants feel relaxed, explaining what you are doing and why. Regina stressed the importance of finding a good space for interviews.

Another important lesson was identified on Day 4 about communication during interviews: if people don’t know why you are asking questions it may affect their answers.

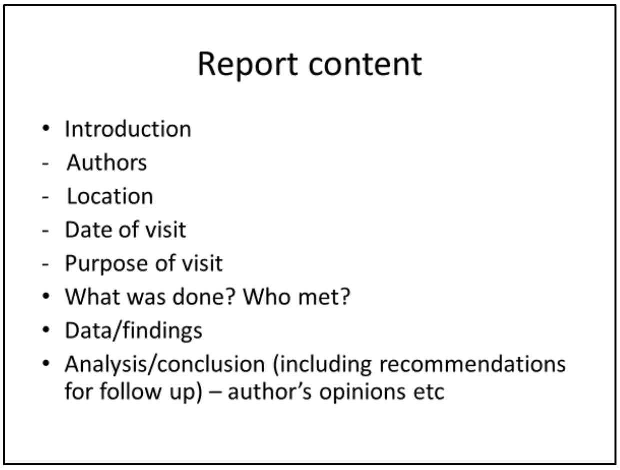
Jack Baynes suggested that it is a good idea to have a mixed team (one woman, one man) for interviews, especially if women are interviewed.

Overall, the exercise provided valuable experience in planning and performing interviews.

Concluding discussions
Note: the workshop finished at lunchtime.

<u>Report formats and requirements</u>

Bob discussed the need for a file naming system for reports and data files. Inconsistent file names and file dating made data management in Phase 1 difficult. A system was proposed. (Details are not included here as the system was subsequently amended.)



There is no strict format for field reports, but there are requirements for content. (Figure 2).

Figure 2.

Ethics
All research involving humans carried out by Australian universities, must, by law have approved ethics protocols. As the ACIAR project is being led by USC, ethics clearance is required and all partners are required to agree to the approved protocol.

The key requirements are that research participants must

- be informed of the purpose of the project
- assured that they have full rights to refuse to participate or to withdraw from the project;
- assured that they will not be identified in reports or publications unless they agree to be included.

Researchers must provide information to potential research participants before interviews or other research activities. This is in the form of a RPIS (Research Participant Information Statement). In the case of this project, oral agreement is acceptable. The contents of the RPIS must be explained to all participants and copies of the RPIS (in *tok pisin*) must be provided if requested.

Preliminary planning for data collection

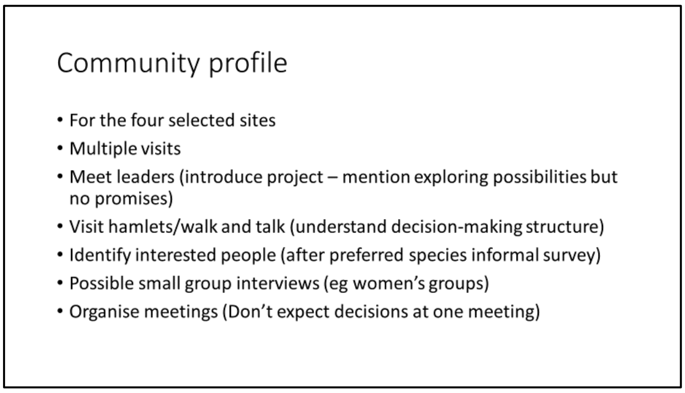


Figure 3

In this final discussion the focus was on the type of data and process involved in collecting preliminary community data in the form of a "community profile". These profiles, only required for the sites selected for project activities, need to include information on community structure, tenure and land use (See Figure 3).

ACKNOWEDGEMENTS

As facilitator, I would like to thank all the participants for their engaged participation during the workshop. Thanks to the RAIL Guesthouse staff for looking after us, to RAIL for providing the facilities and to Will Unsworth and Melinda Thom for their help in organising the workshop. I would also like to thank Kanchana Wiset for helping with workshop preparations, especially for helping to identify litrtaure and resources.

LIST OF APPENDICES

Appendix 1
Readings provided before the workshop

Note: Appendices 2-6 are in a separate pdf file.

Appendix 2
Stakeholders and stakeholder analysis

Appendix 3
Gender landscapes and agroforestry matters (Regina Kagl)

Appendix 4
Introduction to social science methods

Appendix 5
Role play scenarios and guides for interviewers

Appendix 6
Action research

Appendix 1

Readings provided before workshop

Basnett, BJ, Marlène Elias, Markus Ihalainen and Ana Maria Paez Valencia (2017) *Gender matters in forest landscape restoration: A framework for design and evaluation*. CIFOR Research Program on Forests Trees and Agroforestry

Emadi, Mohammad Hossein (2005) “Research through action with nomadic pastoralists in Iran.” From Julian Gonsalves, Thomas Becker, Ann Braun, Dindo Campilan, Hidelisa de Chavez, Elizabeth Fajber, Monica Kapiriri, Joy Rivaca-Caminade, and Ronnie Vernooy(eds) *Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A sourcebook.* IDRC books online.

Fisher, Bob and Philip Hirsch (nd) “Social science concepts for natural resource and environmental management.” Unpublished Australian Mekong Resource Centre, University of Sydney.

Fisher, RJ and WJ Jackson (2002) Action research for forest landscape restoration. Unpublished paper, IUCN The World Conservation Union.

Fisher, Robert, Stewart Maginnis, William Jackson, Edmund Barrow and Sally Jeanrenaud (2008) “Scale, landscapes, boundaries and negotiation”, chapter 4 in Robert Fisher, Stewart Maginnis, William Jackson, Edmund Barrow and Sally Jeanrenaud (eds) *Linking Conservation and Poverty Reduction: Landscapes, People and Power.* London: Earthscan.

Appendix 2 Stakeholders and stakeholder analysis

Stakeholders and stakeholder analysis

"Enabling community forestry in Papua New Guinea"

ACIAR FST/2016/153

Social Science Workshop

22-26 January 2018

University of the Sunshine Coast

Bob Fisher

1

Pluralism

- Multiple interests pervasive in environmental and NRM issues
- Quite different "interests" in outcomes
- Often conflicting
- Often based on quite different perspectives and world views

2

- View that there is a single rational answer

  Problem: does not accommodate variety of views

  ("Instrumentalisation of science")
- Alternative view that "all values are… contextually defined" (Anderson et al. 1998)

  Problem: how to deal with differences?

3

Stakeholders

- Different categories of people who are affected by an NRM decision
- Different categories of people who can affect the outcomes of NRM
- (WCD: Rights and risks approach)

4

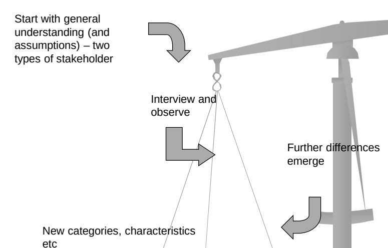
Stakeholder analysis

- "Stakeholder analysis can be defined as an approach for understanding a system by identifying the key actors or stakeholders in the system, and assessing their respective interests in the system"

  (Grimble quoted in Ramirez)
- A methodology for understanding diverse interests related to environment and natural resource management

5

Stakeholder analysis = Disaggregation



6

Issues for stakeholder negotiations

- Need for building stakeholder fora
- Try to meet variety of objectives
- Problem that powerful tend to dominate
- (How can we achieve a level playing field?)
- Consensus and decision-making
- Pluralism can be an excuse for overriding interests of the poor or other minority interests – especially for ignoring rights based approaches

7

- Pluralism is a philosophy or policy, not a methodology
- How can we achieve pluralist compromise?
- Can't please everyone – but can we met some of everyone's needs?

8

Understanding stakeholders

- The relative power and influence of each stakeholder
- The importance and influence they have
- The multiple "hats" they wear
- The networks and coalitions to which they belong

[Ramirez 1999]

9

Problems

- How do you ensure that weak stakeholders get equal access?
- How do you decide which stakeholders are more "important" or legitimate or which should be given priority
- Issues of representation and legitimation

10

Whose interests count?

"...the various stakeholders have different interests, rights and responsibilities, which can be placed on a continuum of relevance for day to day forest management."

[*Who Counts Most: Assessing Human Well-Being in Sustainable Forest Management.* 1999 CIFOR Criteria and Indicator Toolbox Series 8-C]

11

Creating level playing fields?

The problem:

- Negotiations cost time and money
- Often dominated by technical language
- Some sub-groups from a community may have better relationships with outsiders
- Parameters set in advance
- Expectations and roles of representatives

[See Fisher et al 2008]

12

- *Some possible "solutions"*
- Neutral facilitator (trusted "honest broker" without vested interest in particular outcomes)
- Advocates/supporters (especially on procedures)
- Assistance in preparing case
- Shorter meetings with intervals between
- Clear mandates for representatives

13

Slide from Kanchana

14

TABLE 4 Type of Stakeholder and Level of Involvement in the Forest Landscape Management Plan (FLMP)

Type of stakeholder	Level of involvement
Key stakeholders	Active involvement in all stages of the public participation process (first and second consultation stage)
Primary stakeholders	Active involvement in the first consultation stage and passive involvement in the other stages (information)
Secondary stakeholders	Passive involvement in all stages of the public participation process (information)

FIGURE 2 Onion diagram of the main stakeholders involved in Italian Forest Landscape Management Plans (FLMPs).

Example of mapping technique

Levels of stakeholders in Ghana's forests

Source: Kotey et al. 1998

15

GENDER LANDSCAPE AND AGROFOREST MATTERS

Enabling Community forestry in Papua New Guinea
Project Number - ACIAR/FST/2016/153

1

Introduction

- Objective
- Gender Concept in Community Forestry
- What is Gender
- Gender Concept in PNG
- Equal Participation
- Why Gender
- Right Approach
- What is expected
- Gaps in Community

2

Objective

- To understand gender difference and approaches in agroforestry and landscape
- To understand the role of women in decision - making is crucial in community forestry.
- To understand women participation and empowerment in agroforestry and landscape is important in socio-economic and sustainability.

3

Gender Concept in Community Forest

What matters –

- The landscape and forest is usually men's business, they are the decision makers and women are the doers.
- Many parts in PNG, land conflicts and structural discriminate against women and marginal groups of people are common and obvious – (Women, young girls and boys, disable and older people).

4

What is Gender?

Gender:
The experience of being female or male

- Differs from culture to culture

Gender is established through a socialization process:

- The process whereby women and men learn the "proper" ways a woman or a man should think, feel, and behave

- Defined behavior/thinking for women and men = **Gender roles**
- Defined tasks, responsibilities for women and men = **Gender division of labor**
- Defined access to and control of property/opportunities = **Gendered access & control**

5

Gender Concept in PNG

- PNG society is seen as "egalitarian"
- The fact that few PNG cultures have hereditary chiefs and it is common for men to compete with one another to be leaders (PNG Gender Assessment 2011-2012).
- This egalitarian ethic does not extend to gender relations – in most cultures and males have higher status than females.

6

GENDER EQUAL PARTICIPATION

The importance of gender participation in the community forest is to ensure that women and men at all levels have **equal voice**. Which can influence in strategic decisions related to forest and land that contributes to substantive equality in outcomes for both women and men.

7

Why Focus on Gender

There are three aspects when it comes to gender and forest:

- equal opportunities
- equal treatment
- and equal entitlements

Gender equality overcomes stereotypes, prejudices, and other barriers so women and men can contribute to and benefit from economic, social, cultural, and political developments in society at the same level.

(Papua New Guinea National Policy for Women and Gender Equality 2011-2015)

8

Why focus on Gender (Cont.)

- The community forest encourage women participation.
- Women involvement at the beginning of the project is critical, it helps to understand the rights of the community of both women and men.
  - in terms of decision making
  - the distribution of (labor) costs and benefits
  - enhance the capacities and the wellness of community engagement in the project.

9

Right Approach

- making women's as well as men's concerns, needs and experiences an integral part of the projects so that women and men can benefit equally. (Will it work? If not why not)
- In fact number of studies have found that encouraging women participation have enhance the effectiveness and sustainability of forest management,

10

What is expected from Community forest

Community Forest -

- Will contribute to their livelihood

(the question is how)

- It looks at the longer term – Medium term and short term and the sustainability of the project

11

Gaps in Community Participation

Name three gaps in the community	Name three possible ways to address these gaps
1	1
2	2
3	3

12

Some Possible Gaps

Gaps in the status and participation of women and men could hinder the overall project outcomes

Project outcomes that may close the gaps in the status and participation of women and men

- Specific measures to avoid/ mitigate potential gender constraints

13

Thank you

14

Introduction to social science methods

Bob Fisher

Social science methodology and planning workshop

Ramu 22-26 January 2018

"Enabling community forestry in Papua New Guinea

ACIAR FST/2016/153

University of the Sunshine Coast

1

Qualitative research

- Dialogue; semi-structured interviews
- Group interviews; Focus groups
- Participant observation

2

Why use qualitative methods?

- Good to identify things you didn't see as possibilities
- Good for understanding "why"
- Can be followed up or confirmed by quantitative methods (especially quantitative surveys)

3

Questionnaire surveys

- Problem if you don't already know the range of possible answers
- i.e. need to know a fair bit first

4

Interviews

- Dialogue
- Semi-structured
- Structured

5

Group interviews/focus groups

- Focus group specific type of group interview (not just any group interview)
- Group dynamics – synergies arising from interaction
- Group composition/Recruitment of participants: Homogenous vs heterogeneous?
- Advantages/disadvantages of each
- Link with stakeholder analysis
- Limitations

6

Ethnography and participant observation

- Ethnography is first of all a type of "product":

  An analysis or description of a particular social or cultural system as a system (holistic)

- It has also come to mean a broad research approach associated with that sort of product

7

Ethnographic methods

- Participant Observation is the core method
- PO is always combined with interviews (or "conversations")
- Other common methods used, not exclusively ethnographic:
  - Semi-structured interviews
  - Group interviews
  - Transect walks
  - Mapping
  - etc
- Eclectic methodology

8

Participant observation

- Participating in a functioning social or cultural system
- Scale varies
- PO is NOT "participatory" observation

9

Examples

10

What is ethnography good at?

- Understanding the meaning people attach to things
- Good if you don't know what the answers might be
- Good for following processes (watching decision-making as it happens etc) ["Event ethnography"]
- Allows you to follow the unexpected

11

- Ethnographic approaches enable you to identify inconsistencies between what people say and what they do

12

The basic concept of “doing ethnography” is simple, but ethnographic research needs structure

13

Methodological issues

- What can be said about qualitative methods?
- ✓ What you will do/did?
- ✓ Mention tools and techniques
- ✓ Validity, verification, generalisation
- ✓ Philosophical issues, such as representation of other; subjective; interpretive

14

Appendix 5
Scenario briefs and guides for interviewers

Scenario 1

Your role:

You are a clan leader in a village where a logging company wishes to log large areas of forest. You are supporting the logging company's offer.

Many of the villagers oppose the company's offer and some accuse you of secretly being in the pay of the logging company.

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario 2

Your role:

You are a clan member in a village where a logging company wishes to log large areas of forest. You are against the logging company's offer.

You are a son-in-law of the clan leader and, while you are a strong opponent of the offer, you don't want to offend him too much.

Your reasons for opposing the offer include:

- worrying that it is not enough,
- worrying that the clan members will lose access to forest resources
- other ideas.

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario Brief

Scenario 3

Your role:

You are a relatively young member of the clan. You are not sure whether you have the land to use for a nursery, but you want to be involved.

You think the clan will allocate one hectare to you, but you are not sure what limitations/conditions would be imposed.

You have had no training, but you have worked with Bonti's nursery for a few weeks.

You have no spare cash to invest. You have heard that RAIL is offering 250 kina per tonne for firewood, but you are not sure if it is true,

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario Brief

Scenario 4

Your role:

You are a clan member (female) in the highlands. You have heard that a nearby clan wants to protect a watershed forest. You believe an NGO is supplying funding.

That nearby clan's forest adjoins your forest and is directly above it in the catchment.

You are not against the proposal necessarily, but you would like to see a similar program for your clan's forest and have other concerns. (Use your imagination.)

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenarios interviewer guide

Scenario 1

Interview clan leader to find if he supports Logging company's proposal for logging agreement and discuss support by community.

Scenario 2

Interview clan member to see what she he thinks of logging company's offer.

Scenario 3

Interview young clan member to assess interest in setting up nursery and capacity.

Scenario 4

Interview female clan member to assess support for nearby clan's proposal to protect and reforest watershed forest.

Action research

Social science methodology and planning workshop
Ramu 22-26 January 2018

ACIAR Project:
Enabling community forestry in Papua New Guinea

Bob Fisher

1

Outline

- Introduction: What is action research?
- Case study 1: Dryland rice farming in Cambodia
- Case study 2: PNG
- Conclusions

2

"Traditional" research and implementation

Linear process

Identify problem
↓
Develop research solution
↓
Implemented (by extensionists?)

3

Action research is suitable when

- A problem being investigated is very complex
- People don't know where to start in solving a problem, or don't know the next step
- Change involves people with differing perspectives when there is need for a common vision
- The situation or context is changing

4

Action research

- Combines action with research
- Learning (research) is done in order to enable action to be carried out more effectively
- Learning occurs through action, through lessons learned by doing things

5

Definition: Action research is

a process in which a group of people with a shared issue of concern collaboratively, systematically and deliberately plan, implement and evaluate actions. Action research combines action and investigation. The investigation informs action and the researchers learn from critical reflection on the action

6

Action research

- Is a process of learning in order to act more effectively
- Can also generate insights relevant to other situations (research)
- A process of adaptive learning

7

- Not just learning through “trial and error”
- But a careful and disciplined reflection process

8

Characteristics

- Usually a group activity
  - to involve relevant stakeholders
  - to benefit from interchange of ideas
- A cyclical process

9

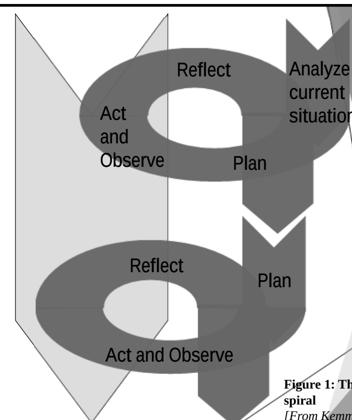
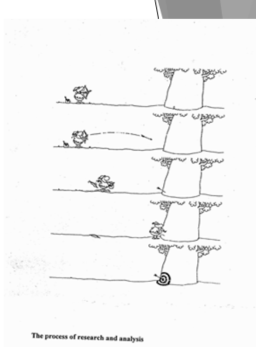


Figure 1: The action research spiral
[From Kemmis and McTaggart, 1988a]

10

Thematic concern

- A concern shared by a group of people involved in action research
- Group members agree there is a need for change, but do not necessarily agree what that change should be or how to bring it about



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Case study 1: Dryland rice agriculture in Cambodia

- Solieng Mak PhD, University of Western Sydney
- IRRI-Cambodia-Australia
- Thematic concern: need to improve rice production and presumed relevance of green manuring

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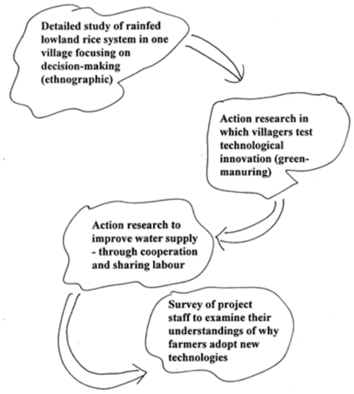

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Case Study: PNG

- Goilala District PNG
- Livelihoods and market access
- Big project, but no implementation
- Very difficult district – problems of law and order, morale and trust
- Not known where to start
- Idea of using action research to get things moving
- Lack of information not the problem (more information would not have helped)

14

First cycle

- National Level: Meeting with National provincial and district staff of DLS
- Assessment of situation and difficulties in implementation
- Follow action research cycle
- Prepare action plans

15

- District level:
- Action research cycle
- Prepare action plans

- Sub-District level:
- Action research cycle
- Prepare action plans

16

Subsequent cycles

- Repeated visits to each level
- Assess progress with action plans
- Make new action plans

17

Approach

- Action plans:
- Breaking implementation into small tasks and monitoring implementation

18

Outcomes

- Worked well – built enthusiasm and trust between extensionists and villagers
- Things happened

19

Important lesson

Importance of getting participation of "stakeholders" from the beginning as members of the team

20

Conclusions

- Action should not be delayed too long – it's not necessary to plan everything in advance
- …and not necessary to do everything at once
- Involve stakeholders from beginning
- Lessons can be applied in other situations

21

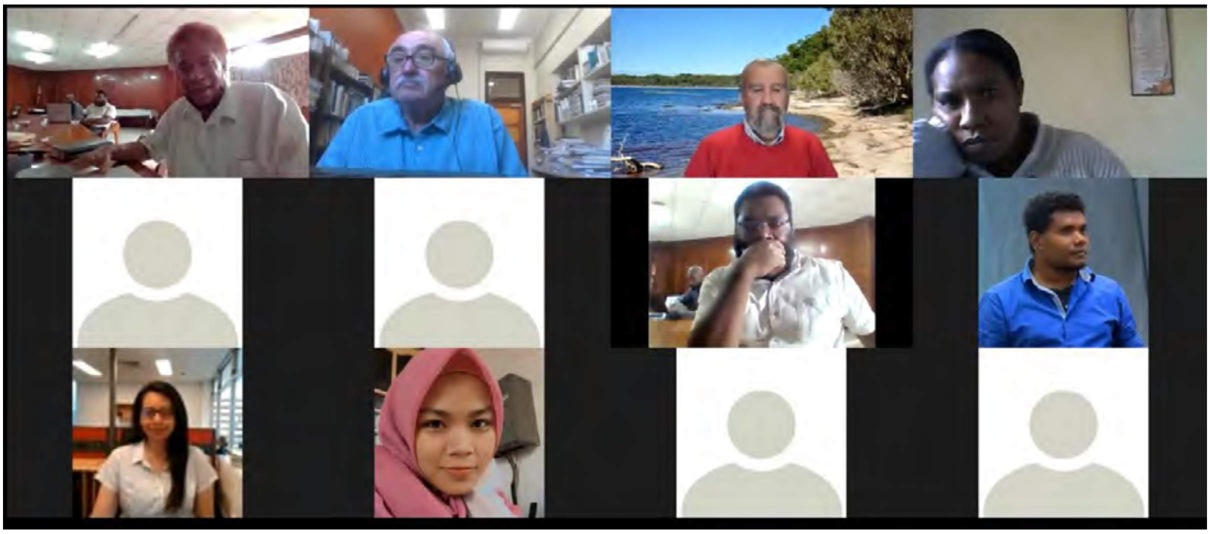
ACIAR project "Enabling community forestry in Papua New Guinea" (FST-2016.153).

Social Science Online Workshop 12-16 April 2021

Report

June 2021

Bob Fisher (Workshop coordinator)
Senior Research Fellow
Tropical Forests and People Research Centre
University of the Sunshine Coast



Background

ACIAR project "Enabling community forestry in Papua New Guinea" (FST-2016.153) held a social science training workshop from 12 to 16 April 2021. Due to restrictions due to the COVID-19 epidemic, the workshop was held on zoom.

The purpose of the workshop was to provide an introduction to social science concepts and methods involved in interdisciplinary research on community forestry for PNG partners from the PNG Forest Authority (PNGFA), the PNG Forest Research Institute (PNGFRI) and Ramu-Agri Industries Pty Ltd (RAIL). Several participants from the ACIAR project "Improving community fire management and peatland restoration in Indonesia" were also invited.

The workshop was co-hosted by the USC project team and the PNG Forest Research Institute. It was facilitated by Dr Bob Fisher from the University of the Sunshine Coast project team and opened by Dr Goodwill Amos the acting Director of the Forest Research Institute. In addition to

USC researchers, at various stages there were sixteen participants from PNG and Indonesia and one PhD student from Australia.

Sessions were held for approximately two hours each morning during the five day workshop. Due to the epidemic, there were no field exercises.

The workshop consisted of:

- Some overview lectures on aspects of social science related to community forestry including applications and methods.
- An opportunity for participants to share their experiences. This was important as some participants had attended early social science training workshops while others had not. The exchange of experiences between participants and between PNG and Indonesian experiences was very useful.
- A number of presentations by participants and USC staff. These included presentations on: community-based training and social capital in Eastern Highlands Province (Vinciana Andrew); research steps for community forestry in the RMV (Ramu-Markham Valley) (Nathan Wampe and Zephaniah Waviki); perceptions and behaviour towards fire in peatlands in Indonesia (Nafila Izazaya); lessons learned from applying social science research in PNG (Kanchana Wiset); experiences in community forestry in PNG (June Mandawali); case study of small scale informal forestry markets in PNG (Micah Scudder); tenure and landscape restoration in the RMV (Will Unsworth).
- Practice sessions on interviewing skills.
- Reflections on lessons learned during the workshop.
- Reflections on ways to apply social science in future work.

Participants

The workshop participants were:

PNG

RAIL

Nathan Wampe (M)
Zephaniah Waviki (M)
Diane Mirio (F)

William Unsworth (M)[1]

FRI

June Mandawali (F)
Haydrian Morte (M)
Gedisa Jeffrey (M)
Anton Lata (M)

PNGFA

Warea Andasua (M)
Vincianna Andrew (F)
Elizabeth Kaidong (F)
Claude Saliau (M)

Indonesia

Nafila Izazaya (F)
Agus Kuniawan (M)
Ari Nurlia (F)
Acep Akbar (M)

Australia

[1] Formerly RAIL, now New Britain Palm Oil Ltd. Current USC PhD student working on Ramu-Markham Valley/RAIL.

Kanchana Wiset (F) PhD student researching in PNG

Total participants: 17

Female: 7

Male: 10

Participants by country:

PNG: 12

Indonesia: 4

Australia/Thailand: 1

Resource persons

University of the Sunshine Coast (Resource Persons)

Bob Fisher
Grahame Applegate (Team Leader)
Micah Scudder
Nestor Gregorio

PNGFRI
Amos Goodwill (Acting Director FRI)
Nalish Sam (Acting Deputy Director FRI)

Notes

1. The workshop focused on qualitative research rather than quantitative research. This was because such a short workshop can only have a limited focus.

2. This report does not include detailed records of discussion or content. It is intended to provide a record of the overall approach and topics. Participants have been provided with copies of all presentations.

Day 1

[Note: Due to technical difficulties participants at FRI joined slightly late so the opening by Mr Goodwill Amos was delayed.]

Workshop introduction
(Bob Fisher)

Participants - self-introductions

Presentation: Why is social science important in forestry? Some global examples.
Bob Fisher

This presentation covered a range of topics including:
-Examples of social science topics relevant to forestry and some examples.
- The story of community forestry using the case of Nepal.
-Lessons from international experiences.
- The example of Non-timber Forest Products.

Workshop opening
Goodwill Amos, Acting Director FRI

Discussions
There was a general discussion of topics raised by participants related to social sciences in forestry. One topic discussed was research on forest fires This was raised as both Nafila and Nathan have done work on the topic (mentioned in self-introductions). Another was about REDD+ in Nepal (Elizabeth).

Nalish Sam emphasised the relevance of social science, saying there is no alternative to extension forestry working with communities.

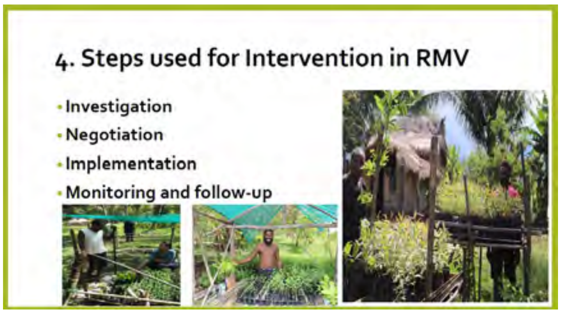
Day 2

Presentation: Social capital in community empowerment and engagement.
Vinciana Andrew

The presentation focused on community-based training emphasising that social capital is linked to education.

Presentation: Social sciences research steps initiated for community forestry in the Ramu and Markham Valleys.
Nathan Wampe and Zephaniah Waviki

The presentation focused on the intervention and research activities in the RMV.



Presentation: How do invested efforts alter Perceptions and actual behaviour towards fire usage in tropical peatlands? A comparative study across three districts in Indonesia.
Nafila Izazaya

The presentation dealt in detail with research methods used in the project. In summary they are:

- Community questionnaires
- Stakeholder census
- Quantification of actual fires and fire behaviours.

The mix of social science methods and physical science was an important contribution to the workshop.

Presentation: Lessons learned from applying social science research in Papua New Guinea.
Kanchana Wiset

This described the qualitative methods used in a study in the RMV. The methods included interviews, group interviews and landscape visualisation, in which individuals and small groups draw landscapes as they perceive or imagine them. This enables the researcher to probe the reasons for particular land use patterns.

Presentation: Introduction to social science methods.
Bob Fisher

The discussion presentation focused on qualitative methods. (This is the focus of the workshop.) The main methods discussed were:

- Dialogue and semi-structured interviews.
- Group interviews and focused groups.
- Participant observation.

Day 4

Presentation: Stakeholders and stakeholder analysis.
Bob Fisher

Discussed the concept of stakeholders, why stakeholder analysis is important and ways to identify and understand stakeholders.

Presentation: Experiences of community forestry in PNG.
June Mandawali

June's presentation gave a brief overview of community forestry in PNG based on her experiences. She also identified key lessons she had learned.

Presentation: Descriptive case study on small-scale forestry informal markets in PNG.
Micah Scudder

The research described followed a mixed methods approach. It included semi-structured interviews and the mapping of relationships between actors.

Role play exercise
Participants were briefed on this exercise on Day 2. Three scenarios for interviews were provided and for each of these an interviewer and interviewee were selected.

Information sheets were provided for the roles that the interviewee and the interviewer. They did not see each other's briefs. (The role play briefs are in Attachment 1.)

The role plays were carried out and the other watching participants commented on interviewing techniques aiming to identify lessons learned.

This was followed up by a presentation on interviewing skills.

Presentation: Interviewing skills
Bob Fisher

Day 4

Presentation: Unpicking the bundle of rights. Land tenure and implications for FLR in the RMV.
Will Unsworth

In this presentation, Will outlined issues he plans to address in his PhD work, which began when he worked at RAIL. The presentation raised a lot of issues in discussion. It also provided an opportunity for participants to discuss the complete differences in social structure between PNG and Indonesia.

Exercise on data analysis
Nathan and Zephaniah shared some information on the Umi agroforestry demonstration plot. The information, extracted from a visitors' book, related to visits to the plot by people from other villages and some visitors from further away. The exercise was to analyse the data to show the impacts of the demonstration plot.

Participants identified the importance of factors such as the types of questions visitors asked, where visitors came from, gender differences etc.

Exercise on planning research
Bob presented some slides on research planning. The slides identified steps in research planning. Four breakout groups were formed to identify a social science

research project and then to plan it, flowing the suggestions in the slides.

Some of the breakout groups were made of people in a single location. Others had to be undertaken by zoom.

The breakout groups then separated to plan their separate projects. 30 minutes were allocated to the exercise.

At the end of the breakout period, each group presented its results.

Topics and participants were:

Group 1: Identifying effective communications channels for fire prevention programs.
Nafila Izazaya, Acep Akbar and Will Unsworth.

Group 2: Case study of effects of COVID-19 on fresh produce.
Gedisa Jeffrey, Haydrian Morte, Anton Lata, Warea Andasua

Group 3: REDD+ policy framework.
Diana Mirio, Zephaniah Waviki, Nathan Wampe

Group 4: Coffee agroforesty system.
Claude Saliau, Elizabeth Kaidong, Micah Scudder, Viniciannna Andrew
Group 4 presented on Day 5.

Day 5

The aim of Day 5 was to round up the workshop.

Bob stressed that the workshop aimed, as far as possible, to apply experiential learning in which participants learned through practical exercises. Of course, this was complicated by the limitations of zoom (no field trips etc), but experiential learning was the general intention.

The workshop mixed presentations with exercises and as much discussion as possible.

Two further topics were the subject of brief presentations, both by Bob.

Presentation: Report writing and note-taking

Presentation: Human ethics

Following human ethics protocols is a legal requirement for any university research in Australia. This applies to all ACIAR projects and international partners in the projects.

The presentation explained the approach and implementation of ethics. The experiences of participants in applying human ethics were discussed.

Applying the lessons from the workshop: Discussion

All participants were asked how they intended to use the workshop findings. Some of the responses were:

- In PNG forestry is about land and the people. We work with people anyhow. This is important and useful information.
- The workshop will help with an emerging project.
- The workshop has given an opportunity to reflect on what has been done.
- This will be useful for a current masters project.
- I already unconsciously use some methodology. I can go through the data/methodologies.

- The lessons can help with he ACIAR fire project in Indonesia.
- I am a physical science researcher, but this is useful for communication and understanding (Indonesian participant).

Final comments

Bob stressed the importance of understanding stakeholders and stakeholder analysis.

He explained that all presentations would be sent to participants or, in some cases, had all been sent.

End of workshop

Evaluation and feedback

Following the workshop participants were asked to provide feedback by email on a number of questions.

Question 1:
Did you enjoy the workshop and find it useful?

Question 2:
Which topics were most useful for you personally?

Question 3:
Are there any other topics that you think could have been covered?

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better?

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?
Attachment 2 contains the feedback provided.

Participants expressed satisfaction with the content of the workshop and clearly appreciated the opportunity for a change from the pressures of the epidemic. Given the lack of alternative and despite the obvious technical limitations, the use of zoom was acceptable.

There was enthusiasm for further social science training and a number of topics were identified.

Acknowledgements

I would like to thank all the participants and USC staff for their interest and enthusiasm. The workshop was fun and there were a lot of good ideas discussed.

I appreciate the support of Amos Goodwill and Nalish Sam (Acting Director and Acting Deputy Director of FRI, respectively) for their support and encouragement of the workshop.

Attachment 1

Scenario briefs for role play exercise on interviewing

Scenario briefs for interviewees

Scenario 1

Your role:

You are a clan leader in a village where a logging company wishes to log large areas of forest. You are supporting the logging company's offer.

Why do you support it?

Many of the villagers oppose the company's offer and some accuse you of secretly being in the pay of the logging company.

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario 2

Your role:

You are a clan member in a village where a logging company wishes to log large areas of forest. You are against the logging company's offer.

You are a son-in-law of the clan leader and, while you are a strong opponent of the offer, you don't want to offend him too much.

Your reasons for opposing the offer include:

- worrying that it is not enough,
- worrying that the clan members will lose access to forest resources
- other ideas.

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario 3

Your role:

You are a villager near a site where a peatland fire has taken place. You are being interviewed by a researcher about how the fire started and whether it was deliberate.

What do other members of the community think?

Instructions:

Use the information above to guide your answers to questions. You can add to all this and use your imagination as much as you like.

When answering questions you should answer questions truthfully, but you don't have to offer information unless asked and, if you like, you can tell the interviewer as little as she/he lets you get away with. You can also just avoid answering questions.

Scenario brief for interviewers

Scenario 1

Interview clan leader to find if he supports Logging company's proposal for logging agreement and discuss support by community.

Is there any conflict?

Scenario 2

Interview clan member to see what she he thinks of logging company's offer.

Scenario 3

Interview a villager to find out how a peat fire started and perhaps who started it. Ask questions about what precautions the villagers take about preventing fires and what they do if a fire starts. female clan member to assess support for nearby clan's proposal to protect and reforest watershed forest.

Appendix 2

Social Science workshop feedback

Note: Names have been removed, but otherwise the feedback is in the original form.

Participant1

1. I did enjoy the workshop and found it useful
2. Traits that can be derived out from questionnaires (Example from the RAIL Team)
3. Analysis of social data collected from questionnaires
4. Zoom was the best option available in this time of COVID-19 pandemic
5. I'd really would like for a data analysis workshop for analyzing social science data obtained from questionnaires possibly using R Statistics

Participant 2

Question 1:
Did you enjoy the workshop and find it useful?
I did very much enjoy the week long workshop via zoom. It is very useful to my current social science research project at FRI.

Question 2:
Which topics were most useful for you personally?
As it is my first time to attend a social science workshop I'm eager to learn as much as I can from the topics that were covered last week.

Question 3:
Are there any other topics that you think could have been covered?
A sample of questionnaire for different targeted groups and example of results from a qualitative research would be great, nevertheless, topics selected for last week's workshop fits very well with the time we have.

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better?
As per the circumstances we encountered due to Covid-19 travel restrictions we could not expect more. Great sessions we had, it would be great to have 2 hours in the morning and 2 hours in the afternoon per day.

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?

1. Common statistical software used to analyse qualitative research data

Participant 3

Answer 1: Workshop was useful, although the platform (Zoom) used to execute it was quite challenging, due to technical issues.

Answer 2: I found the Stakeholders and stakeholder analysis, Interviewing skills and planning research exercise useful for me.

Answer 3: I am not sure if stakeholder analysis and stakeholder engagement are the same or not, but I think Stakeholder engagement could also be covered.

Answer 4: Personally, I believe having such an essential component of the project, especially a training workshop like this via zoom, was not satisfactory, due to the technical and ICT issues involved in using this platform, and also the limited timing is also a setback. It could have been better, if the workshop convened all participants physically in a room (old fashioned way), so that we can enjoy the benefits of ample timing and discussions that are beneficial to each participant.

Answer 5: Maybe Stakeholder Engagement?

Participant 4

Question 1:
Did you enjoy the workshop and find it useful?
Yes, it was very useful

Question 2:
Which topics were most useful for you personally?
Methods, Stakeholders & stakeholder analysis, report writing & note taking (all these topics were very useful to me)

Question 3:
Are there any other topics that you think could have been covered?
Just to expound more on the topics under social science research

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily?
Yes but need more time on specific topics, and as well had problems with the stability of internet connectivity and missed out from the discussions or presentations.

How could we make it work better?
Yes, but because of COVID it would not be possible to have everyone in one room. However, it would be more useful to have more practical sessions (after specific topic) to have a better understanding of the concepts or in social science research or it would be to enhance the knowledge already acquired (improving the current set of skills)

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?
Back to question 3. Expound on the information covered in the topics (methods, stakeholder analysis, etc.) presented in this workshop and other topics that were not covered such as;

1. Types of social science research (comparison or difference with **qualitative** & quantitative research to primary and secondary research)
2. methodology approaches/techniques (interviews, participant observation, ethnography, etc.); depends the subject or research problem
3. analysis of qualitative data

Participant 5

Question 1:
Did you enjoy the workshop and find it useful?
Yes, I really enjoyed it and I find it quite interesting and very useful for my current line of work.

Question 2:
Which topics were most useful for you personally?
All of them.

- Importance of “Social Science” to Community Forestry.
- Qualitative research and its methods esp. “ethnography and participant observation”.
- Report Writing and note taking
- Planning Research – Exercise
- Stakeholder and stakeholder analysis
- Interviewing Skills and techniques
- All presentations by the participants. (presentations by Kanchana and Will Unsworth are quite interesting).

Question 3:
Are there any other topics that you think could have been covered?
Analysis of Qualitative Research Data -

- how do we carry out analysis of qualitative research data?
- Are there any qualitative data analysis packages that can be used by researchers?
- How do we present the methods in a paper/article?

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better?
YES. The daily sessions worked satisfactorily via Zoom. Hopefully, the pandemic comes to an end so we all can physically be in one place together for such training.

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?

- Analysis of Qualitative Research Data
- More emphasis on report witting in qualitative research study.
- More emphasis on quality research methods + Interviewing skills and techniques

Participant 6

Question 1:
Did you enjoy the workshop and find it useful?
The workshop was extremely useful. A good amount of social science research work was carried out in RMV since 2018 and this training provided an opportunity for the RAIL team and myself to reflect and place our experience onto the topics discussed.

Question 2:
Which topics were most useful for you personally?
A few topics of discussion stood out for me.
Firstly the exercise was carried out to signify how social science data can be captured and illustrated(Use of Umi data). It provided an opportunity to reflect that there are multiple avenues to capture and portray social science data and the possibilities to show the results. Secondly as I am doing my masters research also on grassland fires in RMV, Nafilla's research on Peatland fires in Indonesia was an eye-opener on the variety of possible social science data that can be taken from it.

Question 3:
Are there any other topics that you think could have been covered?
Classes of social science data (Quantitative/Qualitative? How these data can be grouped /catagorised

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better? Given the pandemic, zoom was of adequate enough for now.

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics? I would suggest we emphasise on a range of different social science data that is available and how they can be captured and catagorised

Participant 7

Question 1:
Did you enjoy the workshop and find it useful?

Dear Bob, the Workshop was a good refresher for some but a new concept for most of us on how to understand the social dynamics in a natural resource management settings when people focal point of discussion.

Question 2:
Which topics were most useful for you personally?

The topics cannot be separate from each other as they all have equal weight towards different scenarios in a given setting. The most important and useful on a personal level will be the Research planning class.

Question 3:
Are there any other topics that you think could have been covered?

Focus Group discussion and Visualization interview are very good lessons that we could expound on.

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better?

Microsoft teams is another platform that we can use but zoom has worked out best for us since COVID restrictions and travel bans.

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?

More training on the Social research planning and methodologies and sampling techniques.

<u>Participant 8</u>

1. I am very happy the workshop because of many principles in social research that I got
2. The most useful thing in the workshop for me was in social research methods
3. I need some of the most common ways of data analysis used in social research
4. Indeed, sometimes workshops using Zoom are not a bit satisfactory, for example voices are often lost and they a bit hampered when dividing the grouf. I don't know how to make it better.
5. Suggestion for short follow-up workshop, If possible, I hope the Teacher can provide a simple case example of a social research that is discussed starting from research planning, implementation, research ethics and data analysis to writing research results in scientific jurnal.

<u>Participant 9</u>

Question 1:
Did you enjoy the workshop and find it useful?

I very much enjoyed the workshop. It was well paced and timed to allow for learning and interaction without becoming overbearing (as online discussions can become!). While I had covered some of the topics before, it was useful to review these topics and learn more on the same.

Question 2:
Which topics were most useful for you personally?

Reconnecting with the project and the team was most useful for me!

Question 3:
Are there any other topics that you think could have been covered?

Hard to gauge the appropriate depth of explanation with a very broad audience, but seemed to cover everything and keeo the audience engaged.

Question 4:
We had no choice but to run the workshop through zoom. Do you think it worked satisfactorily? How could we make it work better?

I think the workshop ran very satisfactorily. A few IT glitches were to be expected, but the presentations were well prepared and the interactive sessions ran very well.

Question 5:
There may be a possibility of arranging short follow-up workshops on specific topics occasionally in the form of one-off two-hour workshops. Do you have any suggested topics?

I wonder about running a workshop on visions for the landscape.

We are yet to really set out a roadmap for what the landscape could look like in the future. While we know that most action will be on family scale plots, a clear vision for the overall landscape will assist in developing clearer mechanisms for policy, extension services and market connections to support individuals in achieving their own goals, as well as achieving the landscape scale benefits of FLR in the valley. I would be interested to discuss this more and assist in facilitating this. Might be that some more stakeholders are needed; PNG biomass, GrowPNG, DAL, Olam, etc..

Perhaps after the land tenure paper, it would be good to discuss this further.

Another one is community entry protocols; Nathan’s presentation reminded me that we once started work on discussing this before; a group paper reporting positive and negative experiences in community entry from the project work, and the risks it can hold for a project.

Preferences for family-based agroforestry in the Ramu-Markham Valleys

Regina Kagl
Nathan Wampe
Melinda Thom
Bob Fisher

June 2018 (updated 2020)

Introduction

This report addresses the following activity in the Project Document:

> *Activity 1.1 under Project Objective 1 is to:* Identify community preferences and site conditions for family-based reforestation.

The report presents the findings of a study carried out in Marawasa (previously referred to as Impu) and Atzunas landscapes in the Upper Markham Valley. These two landscapes have been identified for the first round of family-based agroforestry trials. The study was undertaken as part of the overall social investigation of the two landscapes in order to provide guidance for the design and preparation of the trials. The report is intended to be used as a background document.

The rationale for undertaking the research is the need to provide an understanding of the desires of potential trial participants about what services they want from agroforestry activities. This is required as the trials are intended to be based on participants' wishes and preferences, providing a mix of species that meet their expressed wishes. We want to provide options that are socially desirable and practically viable in technical terms (seed availability, suitability of site conditions and viable species combinations).

As the study was based on a small sample and is not based on a large scale survey, the results are not intended to define what the participants who ultimately take place in the trials individually want. Discussions with individual families engaged in the trial plots will still need to take place.

In the Project Document the study was presented as as an exercise in identifying preferred species. However, this has been reframed. To start the research with participants identifying preferred species risks limiting options to species they know and also risks leading to a "shopping list" of expectations that may be disappointed. The concept in the revised thinking is to begin with identifying what services and benefits people want to obtain from farm-based agroforestry. For example, do they want building materials, poles, fuelwood, foods (fruit, nuts), medicinal plants or some other service? Once these desired products and services are identified, the informants can be asked for suggestions as to what species they think may be suitable, with the understanding that actual options may differ depending on practical and technical issues.

During the study it was stressed to informants that the research team will be looking for suitable options and that, therefore, the species they have suggested may not be available or viable. It was explained that, when plots are being designed, the researchers will suggest various options for meeting their requirements which take into account desired services and viability.

Based on the draft findings of the study, the identified species will be reviewed by the specialist forestry researchers to assess whether suggested species are suitable in terms of the site conditions, availability of seeds/seedlings, costs, possible markets etc. Other options for meeting requirements will be assessed and offered. Based on this assessment, discussions about their involvement will begin with farmers and communities.

Expectations

The ever present risk of raising expectations was important in the study. Any mention of future activities may be interpreted as a promise and rumours spread quickly from informants to others, often without qualifications made about the preliminary nature of discussions. During the study the researchers attempted to make it clear to informants that they would not necessarily individually be involved in family-based trials, that the numbers would be small at first, and that participants in the trial will be identified later.

Methodology

The methodology for the study was qualitative, using informal interview techniques and small group interviews.

Informal interviews

The informal interviews were based on a small number of broad questions. Questions were intended to be open questions not closed questions. The questions were asked in such a way that the answers could be tabulated and, where appropriate, presented in a quantitative form. The interviews were done in parallel with the community profile study.

Small group interviews

The interactive small group interviews utilised the same list of broad questions.

The topics/questions (with instructions to interviewers):

- What would you want to gain from agroforestry plantings?

  Instruction to interviewer: It is important to make it clear that the question refers to the full range of desired products and services, not just "forest'' trees. Other possibilities are sources of food (such as fruit and nuts). In fact it would be stressed that the plots would be multi-purpose.

- Do you have any suggestions about species that you think might be suitable or which you prefer? Why do you think these would be good for the purpose?

  Instructions to interviewers: This topic should be raised only after general expectations have been identified. It is important to explain that we will be looking at what is suitable for the site and what is available. We may suggest other options that can meet the needs.

- For women: Discuss labour availability. Where would they prefer any plots to be? How big can they be?

- Are there any people who have showed an interest in tree planting previously? What sort of trees and where?

Sampling

The sample was a purposive sample. The participants were selected based on the need to obtain opinions from a range of stakeholders, with different interests in land use. It was crucial that the opinions of women were actively sought as they would be be most affected by labour demands etc. Accordingly, it was intended that approximately 50% of informants should be women.

It is essential to recognise that the results of this small study are intended only as guidance for the identification of potential species for the family-based agroforestry trials. The final composition of the plots will be based on further discussion and negotiation between the project researchers and community participants.

Numbers of participants

The numbers of people interviewed individually were:

- Marawasa (10 women F and 11 men)
- Atzunas (10 women and 10 men)
- In Atzunas a group interview involving 3 women and 4 men was held. Of these two women and one male had been previously been interviewed.

Preferences for Services and Benefits from Family-based Agroforestry

Table 1 – Services Desired From Trees – Marawasa (Papua and Karanas)

Marawasa	No of Male interested /13	No of Female interested /10	Total
Fuel (firewood/) charcoal	9	9	18
Food from tree (personal consumption)	6	4	10
Income from selling fruit	3	3	6
Income generated from timber	1	2	3
Materials for Housing construction	10	9	19
Income from the production medicinal trees (Moringa and Noni)		1	1
Shade tree	6	2	8
Tree with medicines	1	1	2

Important points to note from Table 1 are that wood for fuel and construction was a high priority for both women and men in Marawasa. In discussion women were particularly interested in timber for furnishing inside the house. Both men and women pointed out the importance of timber for future generations. The relatively low level of interest in fruit trees for self-consumption probably relates to the fact that fruit trees are already common around home gardens. However, fruit trees are strongly identified as suggested species. Regarding shade trees, some men referred to the need for trade trees in their small cocoa gardens.

Table 2 - Services Desired From Trees – Atzunas

Atzunas	No of Male Interested /10	No of Female interested /10	Total
Fuel (firewood)	4	10	14
Food from trees (personal consumption)	6	5	11
Income for selling fruit	0	6	6
Income generated from timber	2	1	3
Materials for Housing construction	7	10	17

Income from medicinal trees (Moringa and Noni)	1	3	4
Shade Tree	4	2	6
Trees with Medicines	6	1	7

For Atzunas (Table 2), the pattern is largely similar to Marawasa (Table 1). The most notable difference is the greater interest in medicinal plants. This can be attributed to the fact that a student from Unitech visited the village and promoted interest in medicinal plants, mostly Moringa.

Interestingly nobody from either landscape mentioned cocoa as a desired benefit from agroforestry. This should not be interpreted as a lack of interest in cocoa, because many people already grow cocoa around their houses and gardens, and may not naturally see them as products of mixed species agroforestry plots. However, cocoa is suggested as a desired species and community discussions referred frequently to the demand for cocoa.

Species suggested by informants

Table 3 – Species Suggestions - Atzunas

Scientific Name	Common name	Number of women interested /10	Number of men interested / 10	Total
Artocarpus altilis	Bread fruit	3		3
Eucalyptus pellita	Red Gum or Pellita in PNG	5	10? Confirm with Nathan	15
Gnetum gnemon	Tulip	7	10	17
Moringa oleifera	Moringa	2	2	4
Canarium indicum	Galip Nut	3	5	8
Dracontomelon dao	Mon	3	5	8
Syzygium sp	Laulau	6	7	13
Aleurites moluccana	Candlenut		2	2
Barringtonia edulis	Pao		1	1
Terminalia catappa	Talise	1	5	6
Terminalia kaernbachii	Okari Nut	3	7	10
Nephelium lappaceum	Rambutan	2	4	6
Psidium guajava	Guava	6	7	13
Theobroma cacao	Cocoa	5	10	15
Instia bijuga	Kwila		10 confirm with Nathan	10

Table 3 indicates interviewed men in Atzunas are interested in timber trees such as kwila, pellita and cocoa trees. Women are more interested in food trees, such as fruit and nuts.

Table 4 – Species Suggestions Marawasa

Scientific Name	Common Name	Number of women interested / 10	Number of men interested /10	Total
Artocarpus altilis	Bread fruit	3	3	6
Eucalyptus pellita	Red Gum or Pellita in PNG	10	10	20
Terminalia catappa	Talise		4	4
Psidium guajava	Guava	10	5	15
Theobroma cacao	Cocoa	5	8	13

Instia bijuga	Kwila		7	7
	Mogani		1	1
	Teak	1	1	1

Table 2 indicates that both interviewed men and women in Marawasa are interested in pellita trees. Seven men also expressed interest in kwila, but no women did. The women at Marawasa expressed strong interest in fruit species, because they will generate income for the family like breadfruit and cocoa.

General Comments

In Marawasa (Karanas hamlet) the informants expressed a keen interest in trees and wanted to start immediately on family based agroforestry. Some of people volunteered to have family nurseries near their houses. The informants have experiences of setting up nurseries such as for cocoa seedlings, and were willing to do the same with the different species of tree seedlings. They expressed interest in having family nurseries near the family house. As people were not asked about nurseries in interviews, these expressions of interest reinforced the researchers' concerns about raising expectations.

Individual families have had experience in planting trees in their gardens and around their houses. Communities are aware of Eucalyptus Pellita trees which are popular and most of them plant pellita in their gardens mixed with banana and other fruit trees. The communities have grown trees close to their homes and want to plant more, not only for timber but for fruit, medicinal trees and timber for income to sustain their families.

The above points are not specific to the preference study, but bear on the question of potential interest in agroforestry trials.

In Atzunas, the individual families expressed their willingness to participate because the first introductory visit by the project team had already boosted their interest and it was the first time they had visitors from outside coming in to their community. Again, the issue of raised expectations is obvious.

Both male and female members described their needs and benefits to be derived from the different trees and, importantly, preferred local species. They also expressed interest in mixed species. The women requested fruit and medicinal trees for marketing and family consumption. The most repeated need during the interviews was for both male and female was for the trees to be used for house construction. Other needs included and highlighted were medicinal plants, fruits, nuts and fuel (firewood & charcoal). One interviewee mentioned that kwila was available in the past but not any more and requested kwila and pellita seedlings. Pelita was suggested as a good fuel source due to its less strong branches (easy to break) and because it allowed fast cooking. Three interviewees consistently emphasised that tulip and mosong (Ficuscopiosa) trees are needed for the community. They stated that during the dry season these trees provide green leaves (vegetables) for families. Other fruit trees mentioned were laulau, mango, rambutan and guava. Two interviewees claimed to have set up small nurseries with the assistance of their wives for moringa and noni trees. The purpose of cultivating noni trees was to sell to potential markets for noni juice making, however there is no market at present. However, there are local uses as noni and moringa have been used by families for medicinal benefits and sold to other families and nearby communities.

Limitations of the study

1. It is probable that some participants did not clearly understand that the identification of suggested species was not intended to be a shopping list and that actual species to be available would depend on seed availability, technical viability and other factors. This may have raised expectations despite the intention not to do so. This point will need to be emphasised in future discussions.

2. The sample of people interviewed consisted mostly of people who had expressed interest in agroforestry and had previous experience in planting trees. The interviewees were suggested by community leaders. A wider sample may have had different preferences and suggestions. On the other hand, this study aimed to obtain information on preferences and suggestions from people who did have an interest in agroforestry and it is their views that will be most valuable for this purpose as they are potential participants in family-based trial plots.[1] In other words a random sample was not necessary.

Key findings and implications for next steps

1. Interest in agroforestry is common among the people interviewed and there is considerable enthusiasm for establishing nurseries.

2. Women (from both landscapes) expressed the importance of plots not being too large as that would lead to increased work for them.

[1] For the wider research on community views on landscape restoration, land tenure, land-use etc, it is essential that the views of people who have not expressed interest are explored. A larger and more diverse sample is necessary. The preference study is aimed specifically to find out what services potential participants in family-based agroforestry plots might want. <u>The details need to eb decided by negotiation</u>.

3. Women also expressed a strong preference for plots to be located close to their houses.

4. There is some discrepancy between the desired services identified and the suggested species. For example cocoa (for income) was not raised when questions about services and benefits were asked but cocoa was commonly mentioned as a desired species (for income generation). Such discrepancies should be considered when agroforestry “packages” are developed.

5. Despite the researchers’ intentions to avoid raising expectations (although avoiding raising expectations was seen as a forlorn hope), expectations have been raised and these expectations will need to be carefully managed as more specific discussions with potential participants occur. This is a particular risk as it is unlikely that trials will begin before the 2019 planting season and there is a long time for expectations to germinate and lead to disappointment.

6. The purpose of this study is to obtain some indication of the range of services potential participants in the agroforestry trials may be interested in, in order to assist the project forestry team to design agroforestry trials that are both viable and desired by participants. One question that should be considered is whether a single package should be prepared for all trial plots and participants or whether individual variations within the broad package should be negotiated with individual participants.

7. It is clear from discussions directly related to the study and related to the broader social research, that the planting of timber species by non-clan members (such as the husbands of women who have returned to the land owned by their clan of origin) is not generally supported by clans. In order to avoid potential conflicts participants in the agroforestry trials should be restricted to clan members with rights to land by clan membership. <u>This is an important point for participant selection.</u>

8. If the word *diwai* (tree) is used, it’s important to understand that this is generally understood to refer to trees used for wood/timber products. Fruit trees are not automatically understood as *diwai* (trees) unless this is specified. People will respond to the idea of fruit trees if that is specifically made clear. (This is consistent with the traditional foresters common assumption that forests are just for timber.)

Bio-economic Models for Tree-based Livelihood Systems

Report prepared for activity 1.2 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder
May 2020

1 Introduction

This report responds to project activity 1.2 'Develop bio-economic models for tree-based livelihood systems.' The methods intended for this activity were;

'Data for the models will be collected from a combination of interviews with community members, from the literature and expert opinion of CCI and PNGFA staff. Financial modelling in Excel will be undertaken drawing upon previous work, including adapting models developed in ASEM/2010/050 and ADP/2014/013.'

2 Description of the tree-based livelihood systems

2.1 Umi agroforestry system

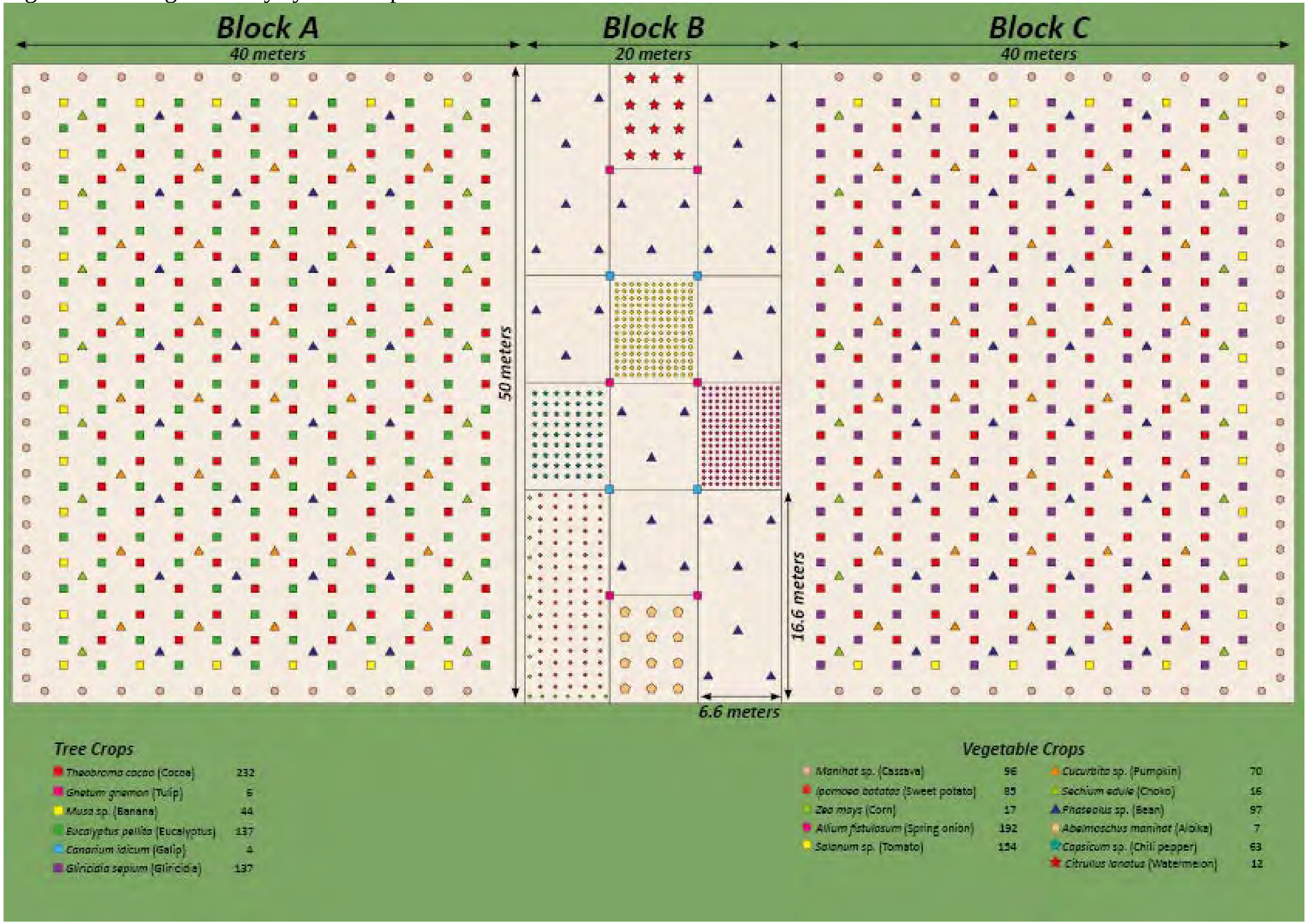
The Umi agroforestry system is based on an agroforestry demonstration site that was developed for this project, designed by Single (2018). This system is divided into three planting blocks; Block A, Block B, and Block C (figure 1).

Blocks A and C have a primary focus of cocoa production, with a total of 232 *Theobroma cacao* (cocoa) trees. Both blocks have a border of *Manihot* sp. (cassava) plants and a border of *Musa* sp. (banana) trees to act as a buffer against fires. The cocoa shade tree species in Block A are *Eucalyptus pellita* (eucalyptus), which were selected for their use as a fuelwood and for home construction materials. The shade tree species in Block B are *Gliricidia sepium*, was selected for its ease of establishment and nitrogen fixing properties. The trees in Blocks A and C are intercropped with *Cucurbita* sp. (pumpkin), *Phaseolus* sp. (beans), and *Sechium edule* (choko) to aid in weed control, nitrogen fixation, and the provision of additional crop income.

Block B has a primary focus of agricultural production. The main agricultural crop is *Ipomoea batatas* (sweet potato), which is grown in a subplot with *Zea mays* (corn). The sweet potato and corn sub-plot are grown at staggered intervals in each of the four corner sub-plots in Block B. The remaining agricultural crops are; *Citrullus lanatus* (watermelon), *Solanum* sp. (tomato), *Capsicum* sp. (chili pepper), *Allium fistulosum* (spring onion), and *Abelmoschus manihot* (aibika). Each of these remaining crops has an adjacent sub-plot that lies fallow every other year and is planted with *Phaseolus* sp. (beans) during the fallow year. Block B also incorporates two tree species; *Canarium indicum* (galip) for nut production, and *Gnetum gnemon* (tulip) to produce leafy greens.

The Umi agroforestry system model utilized a 30-year time horizon. This was selected based on the life expectancy of the cocoa trees (Ryan et al. 2007). Model assumptions and variables are presented in Appendix A.

Figure 1: Umi agroforestry system map



2.2 Cocoa & gliricidia agroforestry systems

The cocoa and gliricidia agroforestry systems is a common method for cocoa production in the Ramu Valley, PNG. This cocoa production system utilizes *Gliricidia sepium* for shade trees. The common spacing measurements for both species are 4 x 4 m. with the *Gliricidia sepium* trees planted between the cocoa trees (figure 2).

Previous research on smallholder cocoa production in PNG indicated that standard cocoa yields are low due to minimal levels of cocoa block maintenance (Curry et al. 2007, Curry and Koczverski 2009, Nelson et al. 2009, Daniel et al. 2011). This research found that . smallholders typically do not prune their cocoa trees or shade trees. Limited weed control was also identified as a challenge, and typically only occurred during the first 2-3 years after tree planting. The weeding was primarily done for harvest access and to promote the growth of intercropped food crops. As a result of the low maintenance, diseases have had a negative impact on cocoa yield. The main pathogen is *Phytophthora palmivora*, which causes black pod rot (Daniel et al. 2011). Other pathogens are *Oncobasidium theobromae*, the cause of Vascular Streak disease and *Erythricium salmonicolor*, the cause of pink disease (Daniel et al. 2011).

Typical smallholder cocoa systems have been described as a ‘low input - low output’ management style (Curry et al. 2007). A previous ACIAR study attempted to enhance smallholder cocoa production by increasing inputs up to a medium level (Daniel et al. 2011). An ‘Integrated Pest and Disease Management (IPDM) system was developed with assistance from the Cocoa Coconut Institute (CCI) in PNG (Daniels et al. 2011). The IDPM system is outlined in a training manual written by Konam et al. (2011). The IDPM system has four options, with each option requiring increased activity inputs. The first option; 1) low, is a continuance of existing practices. The second option; 2) medium, has additional activities that include weed management and tree pruning. The third option; 3) high, includes all the medium level inputs, plus additional chemical inputs; fungicide, insecticide, herbicide, and fertilizer. The fourth option; 4) maximum, includes all the high-level inputs, plus insect vector control chemicals. It was estimated that incorporating the IDPM system can increase cocoa yield from the 1) low input level by approximately 34% (medium level), 55% (high level), and 80% (maximum level) (Daniel et al. 2011 and Pearce 2016).

Two cocoa and gliricidia agroforestry system models were developed (figure 2). One for the low inputs (current practice), and one for the medium-level inputs. Models were not developed for the high-level and maximum inputs because it is unlikely that smallholders would have access to or be able to afford the chemical inputs.

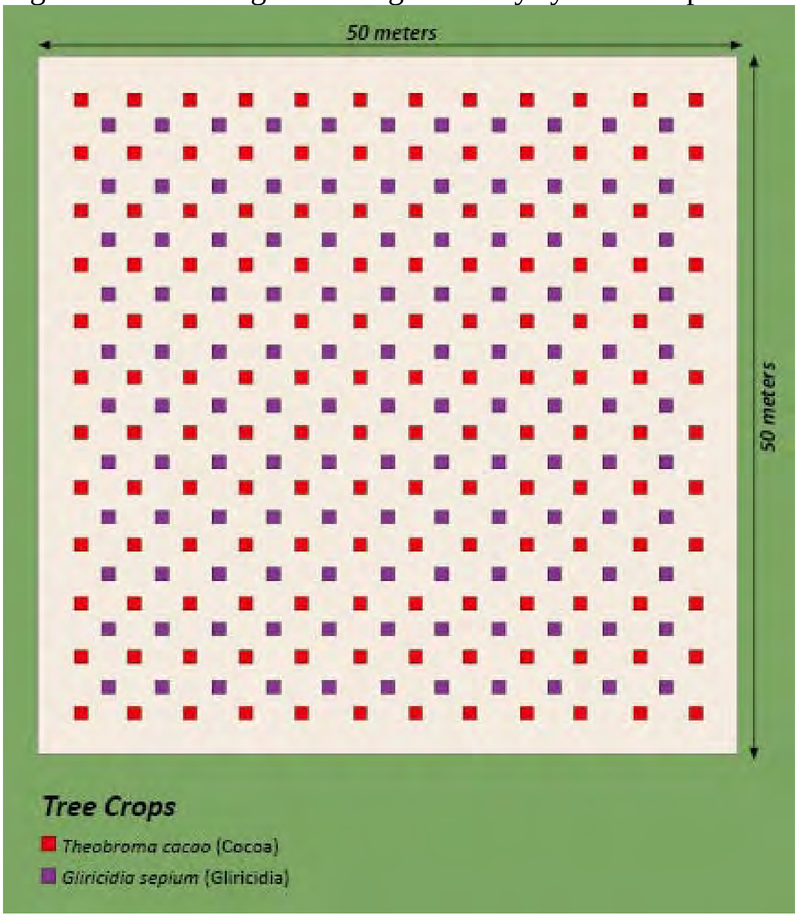
2.21 Cocoa & Gliricidia agroforestry system – Low Inputs

The cocoa and gliricidia agroforestry system (low input) model follows the design discussed above and has a 30-year time horizon. This was selected based on the life expectancy of the cocoa trees (Ryan et al. 2007). Model assumptions and variables are presented in Appendix B1.

2.22 Cocoa & Gliricidia agroforestry system – Medium Inputs

The cocoa and gliricidia agroforestry system (medium input) model follows the same design as the low input model (2.21). The only difference is the increased labour for completing the IDPM medium-level inputs, and the increase cocoa yield. Model assumptions and variables are presented in Appendix B2.

Figure 2: Cocoa & gliricidia agroforestry systems map



2.3 Cocoa, Banana, & Eucalyptus agroforestry system

The cocoa, banana, and eucalyptus agroforestry system is based on system being utilized by a landowner in the Ramu Valley. This system is primarily focused on cocoa production. It initially utilizes banana trees for shade, which are planted with a 2 x 2 m spacing in year zero. The cocoa trees are planted in year 1 with a 4 x 4 m spacing (figure 3a). In year 2, half of the banana trees are replaced with *eucalyptus pelita* trees, which are planted with a 4 x4 spacing in between the cocoa trees (figure 3b). In year three, the remaining banana trees are removed after they have been harvested (figure 3c). This agroforestry system model utilized a 30-year time horizon. This was selected based on the life expectancy of the cocoa trees (Ryan et al. 2007). Model assumptions and variables are presented in Appendix C.

Figure 3a: Cocoa, banana, & eucalyptus agroforestry system – Year 1

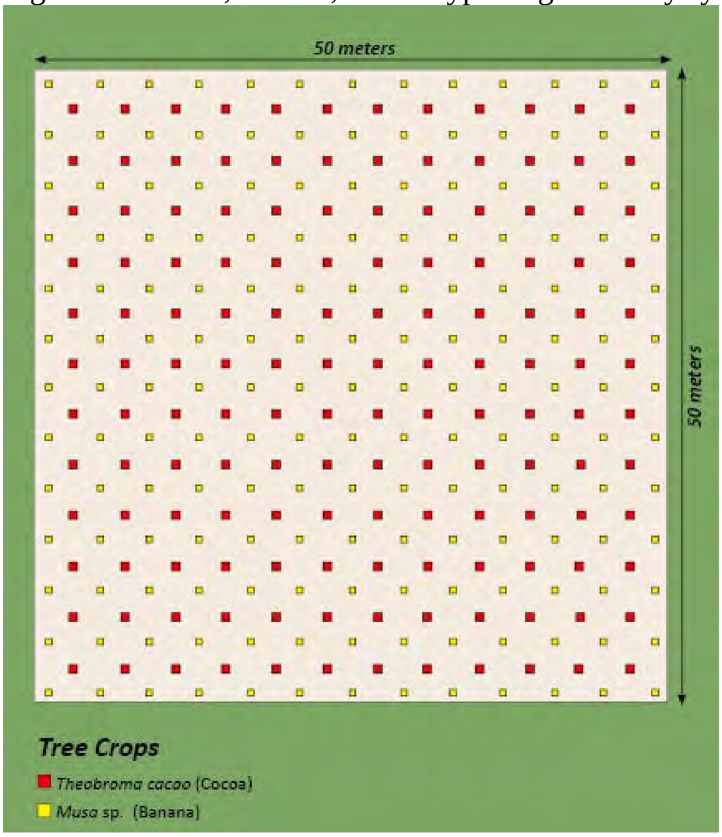
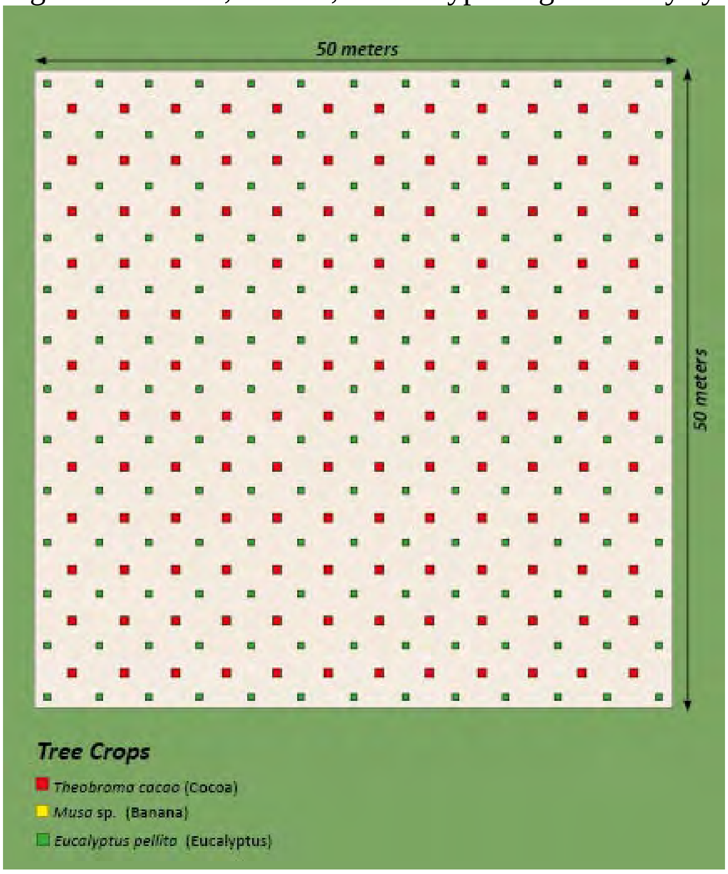


Figure 3c: Cocoa, banana, & eucalyptus agroforestry system – Year 3



3 Methods

3.1 Data collection

A mixed-methods approach was utilized for data collection. Growth and yield data for the specific agroforestry crops was collected from the peer-reviewed literature, final reports from previous research projects in PNG conducted by the Australian Centre for International Agricultural Research (ACIAR), and other published reports. These sources are presented in the appendices; model assumptions and variables.

Site specific data for the Ramu Valley was collected from interviews with key informants during two trips to PNG in 2019 and 2020. An interview protocol was designed to identify activities associated with the labour and cost inputs and the agroforestry crop outputs of tree-based livelihood systems. All interviews were conducted by the author with handwritten notes taken. The interviews were conducted with three project partners; employees of Ramu Agri-Industries Ltd. (RAIL), one project employee that was hired to manage the Umi agroforestry demonstration site, an employee of the Morobe Province Cocoa Board, and one landowner. A total of six interviews were conducted by the author. The purpose of the interviews was to ascertain the approximate required hours of labour for each tree-based livelihood activity, the order that specific activities occured, the expected yield of the crops, and the range of prices received for the crops in local markets.

Two of the project members (RAIL employees) conducted additional market surveys to verify the estimated range of market prices for crops. These surveys occurred in February and March 2020, at two different markets in the Ramu Valley.

3.2 Developing the DCF bio-economic models

A discounted cash flow (DCF) model was developed to estimate the net present value (NPV), the return on labour (in addition to minimum wage), average hourly earnings, and the average labour hours per day. Most smallholders that reside in the study site are semi-subsistence farmers and do get a wage for the labour they provide in their own gardens. However, when choosing to pursue a livelihood activity, they are experiencing an opportunity cost because they cannot use that time to purse an alternative activity. To include this opportunity cost, we used a shadow price, which we selected as the minimum wage in PNG; 3.50 PGK per hour. The return on labour criteria estimates their hourly financial returns in addition to minimum wage. The average hourly earnings criteria assumes that there is no financial cost for labour. The average labour hours per day assumes 240 workdays per year. All the monetary variables are presented in 2019 PNG Kina (PGK).

The DCF model was constructed in Microsoft Excel software.
In developing the models, the principles of capital budgeting of investment projects set out by Dayanandra et al. (2002) and Harrison and Herbohn (2017) were followed. A risk-free discount rate and constant 2019 prices were used to remove inflation from the analysis. The risk-free discount rate was determined by taking the Bank of Papua New Guinea's (BPNG) long-term 10-year bond yield (11.01%), and the average annual inflation rate in PNG for the last 10 years (5.19%) (BPNG 2020). These two rates were incorporated into the Fisher equation (Equation 1) to identify the risk-free/inflation-free discount rate, which was 5.53%.
1) Real Risk-free discount rate = $[(1+r) / (1+i)] - 1$,

Equation 1a)

where r represents the discount rate; and i represents the inflation rate.

As can be seen in Figure 1, the Umi demonstration site has three blocks. Blocks A and C are 0.2 ha in size, and Block B is 0.1 ha in size. To get an even comparison of these different agroforestry systems, the financial variables of the three Umi Blocks were expanded to represent one hectare.

It was also assumed that a portion of the food produced would be consumed by the farmers, and not all sold in the market. It is difficult to determine what the average consumption level would be for each farm family. For this analysis, we assumed that 50% of all edible food produced would be consumed by the family, with the exception of cocoa, which was entirely sold at the market. It was also assumed that the Umi Block B would be divided into four sub-blocks (0.25 ha each) to allow for a fallow period. A sub-block would be farmed for 2 years, and then left to fallow for five years. Just before the first sub-block was about to be fallowed, the second sub-block would begin. This ensured that there would always be a harvestable food crop from Block B. The timing of the fallow period was not perfect from a model perspective and resulted in there being an overlap of two sub-blocks every seven years, resulting in increased consumption and earnings (see figure 4).

3.3 Model assumptions and variables

All the model assumptions and variables have been placed in appendices. The Umi agroforestry model assumptions/variables are in Appendix A. The cocoa and gliricidia agroforestry system model assumptions/variables are in Appendix B1 and B2. The cocoa, banana, and eucalyptus agroforestry system assumptions are in Appendix C.

3.5 Developing the linear programming model

Linear programming (LP) models were developed to identify the optimal mix of the agroforestry systems. LP modelling is a mathematical technique in which a linear function is maximized or minimized when subjected to various constraints. Two LP models were developed. The first LP model maximized the average annual earnings received (Model 1). It was determined that the first model is output that smallholder farmers are likely to pursue to ensure that their food and income needs are provided for consistently through time. The second LP model maximized the NPV (Model 2). The NPV model is the approach that would be utilized from an investment perspective. The results from the DCF model were used for the LP model data inputs. Two agroforestry systems were removed for the LP analysis. Umi Block C was removed because it was almost a mirror image of Block A but had lower average hourly earnings due to *Gliricidia sepium* being used for the cocoa shade trees instead of *Eucalyptus pellita*. *Gliricidia sepium* had higher labour hour requirements for maintenance. The second agroforestry system that was removed from the LP analysis was the Coco-Gliricidia (medium input) system. The results of the DCF model demonstrated that this system had the lowest NPV and average hourly earnings of all the systems.

Both models had to constraints consistently applied. The first constraint was that the minimum area that could be applied to an agroforestry system was 0.1 ha. The second constraint was that a minimum of 0.2 ha had to be applied to Umi Block B. Umi Block B had a primary focus on agriculture production. This second constraint was applied to ensure that a minimum level of agriculture production occurred to ensure that food would be available for consumption.

The other constraints applied to the two models were related to average labour hours per day and the available land. The average labour hours per day that were used were 2, 4, 8, and 16. The available land are that were used were 1 ha, 1.5 ha, and 2 ha. Applying these constraints resulted in each model being run 12 times. A colour-coded decision matrix was developed for each LP model based on the results (see figures 5, 6, and 7).

4 Results

4.1 Agroforestry system DCF analysis results

Table 1 presents the DCF model results for the six agroforestry systems. The three Umi Blocks had a positive NPV, with Block B being the highest. The Banana-Pellita-Cocoa system, the Cocoa-Gliricidia (low input) system, and the Coco-Gliricidia (medium input) system all had a negative NPV, and provided a negative return on labour, indicating that the average earnings from this system are below minimum wage. While the Umi Block B system provided the highest average hourly earnings, it also had the highest daily labour input requirements (assuming that each system was performed with a one-hectare area. Figure 4 presents the average hourly earnings received for each system over time.

Table 2 presents the mean percentage of annual revenues received by the different crops in the Umi agroforestry system. *Theobroma cacao* provided the highest percentage of average annual revenues, followed by *Canarium indicum*, *Manihot* sp., *Musa* sp., and *Citrullus lanatus*.

Table 1: Agroforestry system results (2019 PGK)

	Block A	Block B	Block C	Banana-Pellita-Cocoa	Cocoa-Gliricidida (Low)	Cocoa-Gliricidida (Med).
Net present value	17,471	62,761	15,330	-1,588	-6,983	-23,767
Return on labour	0.80	1.94	0.70	-0.31	-0.41	-1.11
Average hourly earnings	4.30	5.40	4.20	3.20	3.10	2.40
Average labour hours per day	6.4	8.4	6.6	3.6	3.2	5.6

Figure 4: Comparison of hourly earnings of the selected four agroforestry systems

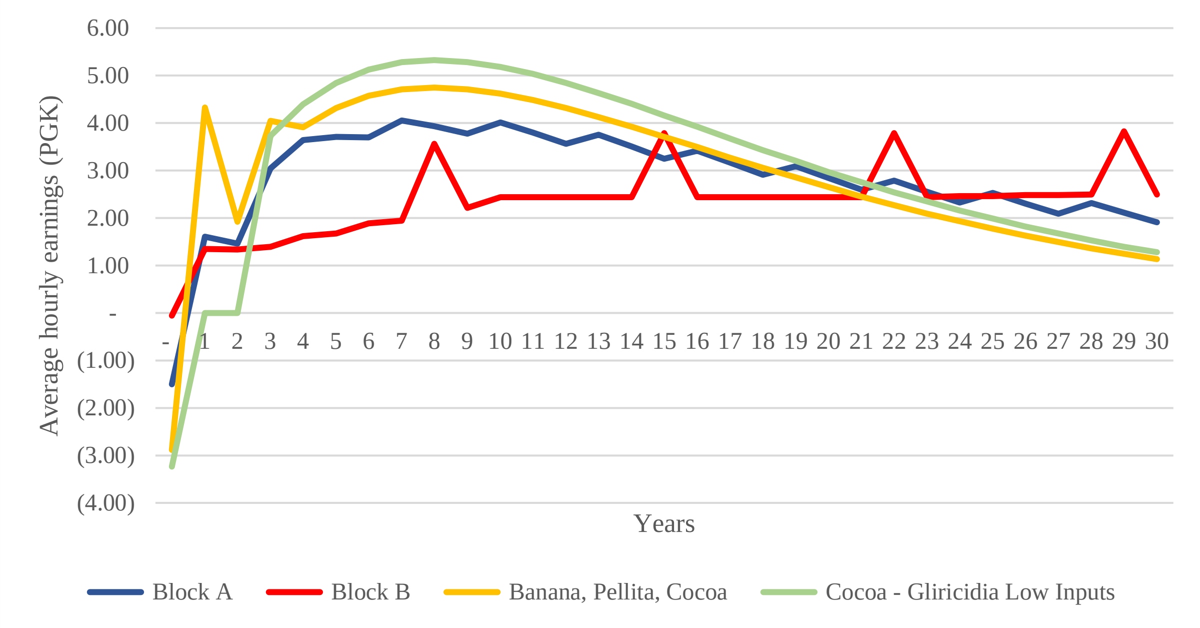


Table 2: Mean percent of annual revenues received by Umi agroforestry system crops (2019 PGK)

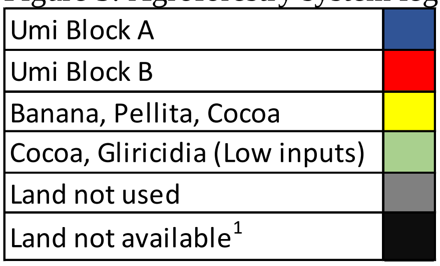
Species	Percent of total
Abelmoschus manihot (abika)	0.4%
Allium fistulosum (spring onion)	0.4%
Canarium indicum (Galip)	13.2%
Capsicum sp. (chili pepper)	1.9%
Citrullus lanatus (watermelon)	5.7%
Cucurbita sp. (pumpkin)	10.2%
Cucurbita sp. Leaf tips	6.5%
Gnetum gnemon (Tulip)	2.1%
Ipomoea batatas (sweet potato)	7.5%
Manihot sp. (cassava)	12.0%
Musa sp. (banana)	8.0%
Phaseolus sp. (beans)	5.5%
Sechiumedule (choko)	2.2%
Sechiumedule leaf tips	0.3%
Solanum sp. (tomato)	2.4%
Theobroma cacao (cocoa)	21.1%
Zea mays (corn)	0.7%
Total	100.0%

4.2 Linear programming anaysis results:

The LP model results presented similar patterns for both models, with the main difference being the selection of the agroforestry systems. Labour was the primary constraint when the average hours per day was set at two and four. In these cases, the total available land was never used. When the average labour per day was increased to eight, all the land was used.

Model 1 preferred a mixture of Umi Block B and the Cocoa-Gliricidia (Low input) system, with some incorporation of the Umi Block A system. Model 2 substituted the Cocoa-Gliricidia (Low input) system with the Banana-Pellita-Cocoa system. The reason for this is that the Banana-Pellita-Cocoa system had a large increase in average hourly earning in years 1 and 2 due to banana bunch sales (see figure 4). In DCF analyses, cash flows that occur in the earlier years have a large impact on the NPV results that cash flows that occur in the later years. Meanwhile, the Cocoa-Gliricidia (Low input) system provided higher average annual earnings across the 30-year timeline. This same pattern is also evident when the average hours/day was set to 16. Model 1 preferred the Umi Block B system because it provided higher average annual earnings, while Model 2 preferred the Umi Block A system because it provided higher earnings during the earlier years of the model.

Figure 5: Agroforestry system legend for figures 6 and 7



[1] One grid of land is not available in each of the 1.5 ha sections to limit to 15 squares.

Figure 6: Decision matrix for maximizing the average annual earnings by agroforestry system type subject to the constraints of available labour and land

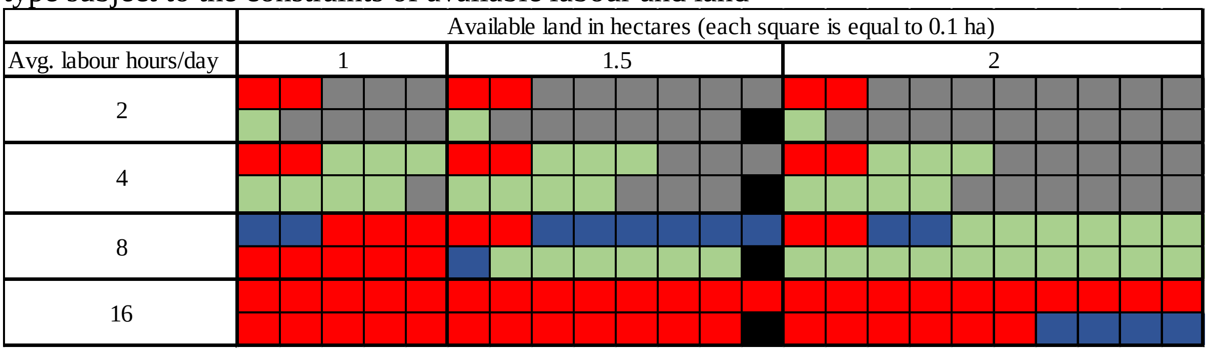
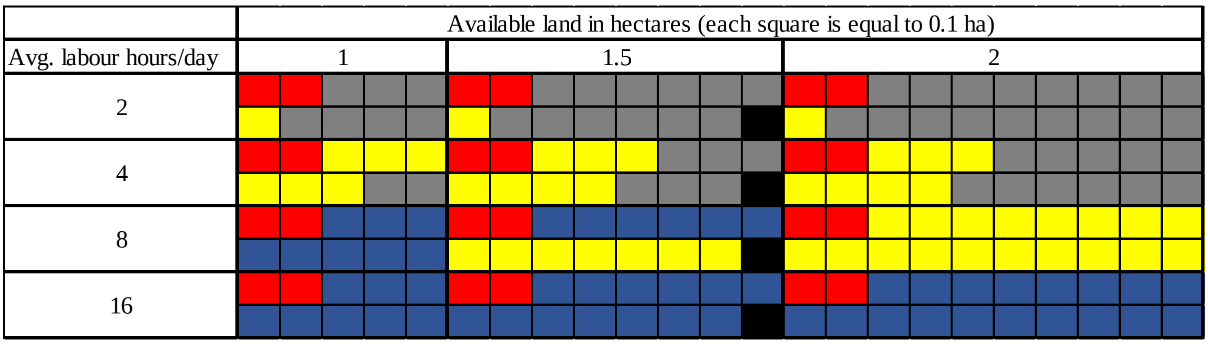


Figure 7: Decision matrix for maximizing NPV by agroforestry system type subject to the constraints of available labour and land



5 Discussion & Conclusion

The objective of this study was to analyse multiple tree-based livelihood systems to determine which options are most suitable to smallholder farmers from an economic perspective. We conducted DCF modelling with six agroforestry systems. The system that focused primarily on agriculture production provided the highest NPV and average hourly earnings but was also the most labour intensive.

During the data collection process, it was found that smallholder farmers pursue multiple livelihood activities as a way of diversifying the risk in case one activity fails. Their available labour is limited, which affects which agroforestry system they would be able to pursue. In addition, farm families vary is sizes. Some families may be large and therefore have more available labour to utilize than a household with one or two people. Furthermore, the land available to them for pursuing different agroforestry systems will vary by family.

Recognizing this, a LP modelling was utilized to develop two decision matrices. These matrices can be used as a tool for agroforestry extension to aid smallholders in their planning process. It is recognized that the matrices presented in this paper are site-specific to the Ramu valley and only reflect a small amount of the different agroforestry systems that exist. Collecting the data to model is labour intensive, which limited the number of agroforestry systems included in this analysis. However, the results from this analysis demonstrate that this method could be quite useful for improving future returns received by smallholder farmers. It is recommended that this approach be applied by extension agroforestry to assist smallholders.

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Appendix A Model assumptions for the Umi agroforestry site

The following assumptions were developed for the Umi agroforestry model. This model had three separate planting blocks; Block A, Block B, and Block C. Theses assumptions are separated by planting block.

A1 Block A assumptions

1. Block A is 0.20 ha in size.

2. There are 116 cocoa trees. These are planted in year 1 using a 2 x 3m spacing.

3. The cost of a cocoa seedlings is 4 kina (Wampe and Waviki 2020).

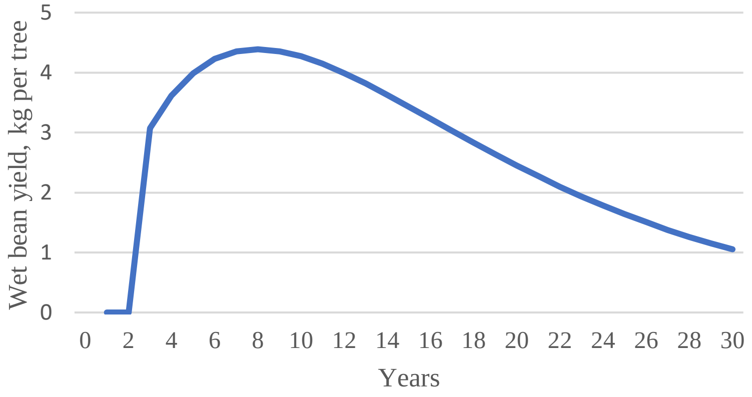
4. Individual cocoa yield per tree is not the same every year. Yield begins in year three, increases every year until it peaks around years 8 – 10, and then declines every year after that. This model utilizes a yield algorithm retrieved from Ryan et al. (2007). This algorithm is for dry annual cocoa produced for an individual tree (kg) in Costa Rica. The algorithm is:

   Yield = exp(-1.1 + ln(a) -0.125a), where a is equal to age of the tree.

5. Modifications were made to the algorithim to more accurately reflect the growing conditions in PNG. According to a previous ACIAR report on small-holder cocoa production, the average annual dry cocoa yield per tree is 1.04 kg (Daniel and Guest 2011). This is 60% higher than the average annual yield presented by Ryan et al. (2007). Hence, the annual yield of each tree was increased by 60%.

6. In PNG, most small-holders sell wet-cocoa and the above algorithm yield is for dry cocoa. A previous ACIAR report on cocoa production in PNG indicates that it takes an average of 2.8kg of wet cocoa to produce 1kg of dry cocoa (Quirke et al. 2007). Hence, the yield per tree was increased by a factor of 2.8 (Figure A1).

Figure A1: Individual cocoa tree wet bean yield curve (kg/tree)



7. The mean price for wet bean cocoa is 1.50 kina/kg. (Wampe and Waviki 2020).

8. There are 138 *Eucalyptus pellita* trees. These are planted in year zero. The model assumes that any timber collected from the *Eucalyptus pellita* trees is for personal use and is not sold in the market.

9. There are 22 banana trees, which are planted in year zero.

10. The banana trees take one year to yield bunches of bananas. In the first year of growth, the bananas yield a mean number of 6 bunches. In the second year this declines to 4 bunches. In year three this declines to 2 bunches. After the third harvest, the bananas are replanted.

11. The sales price per banana bunch varies between 0.50, 2.00, and 4.00 kina/bunch – based on the size of the fruit (Wampe and Waviki 2020).

12. There are 48 cassava plants, which are planted in year zero.

13. Each cassava plant yields a minimum, mean, and maximum kg. of tubers; 1, 2.2, or 4.5 kg/plant. These plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/plant in kg.

14. The sales price of cassava has mean price of 2.00 kina/kg (Wampe and Waviki 2020). In reality, these prices are for a group of cassava tubers and the differences in price points reflect the size and grade of tubers in each group. With the available data, it is not possible to forecast the yield of cassava tubers by grade. The model assumes that each group sold is 1 kg. of tubers.

15. There are 35 pumpkin plants, which are planted in year zero.

16. The mean pumpkin yield per plant is assumed to be 3 pumpkins/plant (Gardentabs).

17. The mean sales price per pumpkin is 1.00 kina (Wampe and Waviki 2020).

18. The mean pumpkin leaf tip yield per plant is 3.94 bundles. This was derived from plant yield estimates published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. This resulted in each plant producing 1.68kg of leaf tips. The model assumes that each bundle of pumpkin leaf tips weighs 300 grams.

19. The sales price per bundle of pumpkin leaf tips has mean value of 0.50 kina (Wampe and Waviki 2020).

20. There are 32 bean plants, which are planted in year zero.

21. The bean yield per plant is 0.60kg. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. The model assumes that the beans are sold in groups, with each group being 0.50kg (2 metric cups). Thus, each plant produces 1.2 groups of beans.

22. The sales price per group of beans has a mean price of 0.50 kina (Wampe and Waviki 2020).

23. There are 16 choko plants, which are planted in year zero.

24. The yield per individual choko plant is 1.73kg. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. The model assumes that the beans are sold in groups, with each group being 0.6kg.

25. The sales price per group of choko has a mean price of 0.50 kina (Wampe and Waviki 2020).

26. The mean choko leaf tip yield per plant is 0.70 bundle. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. This resulted in each plant producing 0.21kg of leaf tips. The model assumes that each bundle of choko leaf tips weighs 300 grams.

27. The sales price per bundle of choko leaf tips has mean price of 0.50 kina (Wampe and Waviki 2020).

28. Labour hours required for the initial land clearing are a mean of 70 hours/ha (Wampe and Waviki 2020). Land clearing happens in year zero.

29. The labour hours required for planting trees/crops is a mean of 0.06. This assumes that it will take 3.5 minutes per tree/crop. In year zero, every tree/crop is planted except the cocoa trees. All the cocoa trees are planted in year 1. In years 1 – 30, all the cassava, pumpkin, and bean plants are replanted twice a year. All the bananas are replanted every three years.

30. The labour hours required for weeding per tree/crop are a mean of 0.04. This assumes that it will take 2.5 minutes to weed around each tree/crop (Wampe and Waviki 2020). The model assumes that weeding occurs every 2 months.

31. The labour hours for harvesting cocoa are 0.46 hours/kg of wet bean yield (Curry et al. 2007). Harvesting of cocoa begins in year 3 and goes until year 30.

32. The labour hours required for harvesting crops is a mean of 0.06. This assumes that it will take 3.5 minutes per individual crop. These crops are; individual banana bunches, cassava plants, pumpkins, pumpkin plant tips, bean plants, choko plants, and choko plant tips. Bananas are harvested once a year. Cassava plants are harvested twice a year. Pumpkins are harvested four times a year. Pumpkin leaf tips are harvested twice a year. Beans are harvested six times a year. Chokos are harvested four times a year. Choko leaf tips are harvested twice a year (Wampe and Waviki 2020).

A2 Block B assumptions

33. Block B is 0.10 ha in size.

34. Sweet potato plants are grown in four subplots. Each subplot grows 85 plants per year. These four subplots are planted at staggered intervals to ensure that there is always a food crop available. When the subplots are not growing sweet potatoes, they are growing beans and will experience 1 bean planting event and three bean harvest events. The model parameters effecting the beans are identical to the assumptions in Block A.

35. Each sweet potato plant yields a mean of tubers 1.18 kg/plant. These plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg.

36. The sales price of sweet potato has a mean price of 2.00 kina/kg (Wampe and Waviki 2020). In reality, these prices are for a group of sweet potato tubers and the differences in price points reflect the size and grade of tubers in each group. With the available data, it is not possible to forecast the yield of cassava tubers by grade. The model assumes that each group sold is 1 kg. of tubers.

37. There are 17 corn plants that are grown in unison with the sweet potatoes, in each of the four sweet potato subplots.

38. The yield of each individual corn plant is 1-3 corn cobs per plant.

39. The sale price for a group of corn cobs (3 cobs/group) is a mean of 2.00 kina/group (Wampe and Waviki 2020).

40. There are 12 Aibika planted per subplots, with 2 subplots of Aibkia. The model assumes that these are planted and harvested twice a year (Wampe and Waviki 2020).

41. The yield per Aibika plant is 4.3 bundles. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. This resulted in each plant producing 1.28kg. The model assumes that a bundle of aibkika is 300 grams, resulting in 4.3 bundles per plant.

42. The sale price for a bundle of aibika is the mean of 0.50 kina/bundle (Wampe and Waviki 2020).

43. There are 192 spring onions which are planted in a subplot, with subplots of spring onions. These are planted and harvested twice a year. They are sold in bundles of 4 (Wampe and Waviki 2020).

44. The sale price for a bundle of spring onions is the mean of 0.20 kina/group (Wampe and Waviki 2020).

45. There are 63 chili pepper plants planted in a subplot, with 2 subplots of chili peppers. They harvested and replanted once a year.

46. The yield per chili pepper plant is 6 groups. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to

identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. This resulted in each plant producing 0.36kg. The model assumes that each chili pepper weighs is 10 grams, resulting in 36 peppers per plant. A group of peppers is typically 6 (Wampe and Waviki 2020).

47. The sale price for a group of chili peppers is the mean of 0.40 kina/group (Wampe and Waviki 2020).

48. There are 154 tomato plants planted in a subplot, with 2 subplots of tomatoes. The tomato plants are planted twice a year and harvested twice a year.

49. The model assumes that each tomato plant produces a mean of 4.56 tomatoes annually. This was derived from plant yield estimates were derived from PNG crop yield ranges (tons/ha) published by Bourke et al. (2009), and crop spacing parameters published by Elfick (2014). The crop spacing parameters were used to identify the number of plants per ha, to convert the Bourke et al. (2009) yields/ha in tons to yield/ plant in kg. This resulted in each plant producing 0.65kg. The model assumes that each tomato weighs 141.7 grams (Greensideup), and that tomatoes are sold in groups of three.

50. The sale price for a group of tomatoes is the mean of 0.40 kina/group (Wampe and Waviki 2020).

51. There are 12 watermelon plants planted in a subplot, with 2 subplots of watermelon, which are planted in year zero.

52. The model assumes that each watermelon plant produced a mean of 3 watermelons (gardeningknowhow.com).

53. The sale price for individual watermelons is the mean price of 10.00 kina (Wampe and Waviki 2020).

54. There are 4 *canarium indicum* trees, which are planted in year zero. The model assumes that these trees do not produce harvestable nuts until year 4.

55. The yield per individual *canarium indicum* tree is the mean of 100 kg of nuts (Bourke et al. 2009).

56. The price per kg. of *canarium* nuts is the mean of 1.00 kina/kg (Wampe and Waviki 2020).

57. There are 6 *Gnetum gnemon* (tulip) trees, which are planted in year zero. They produce leafy greens. The model assumes that leafy greens are harvested from the tree beginning in year 2.

58. *Gnetum gnemon* yield – There is no data on the average leaf yield per tree, or the average leaf harvest per tree. According to Wampe and Waviki (2020), the leaves are sold in groups at the local markets. The model assumes that each tree produces a mean of 30 groups per tree.

59. The *Gnetum gnemon* leaves are sold in groups, with a mean price being 0.50 kina per group (Wampe and Waviki 2020).

60. All the vegetable plants are planted in year zero. They are grown for two years (Years 1 and 2). Then, Block B is placed into a fallow state for five years. At the end of this time, the block is re-cleared and replanted, to be harvested for another two year. Only the galip nut and tulip trees are left in place and harvested annually. This cycle is repeated for the entire 30-year time horizon.

61. Labour hours required for the initial land clearing are a mean of 70 hours/ha (Wampe and Waviki 2020). Land clearing happens in year zero.

62. The labour hours required for planting trees/crops is a mean of 0.06. This assumes that it will take 3.5 minutes per tree/crop. In year zero, every tree/crop is planted. In years 1 – 30, sweet potato is planted 4 times a year in different plots, corn is planted 4 times a year in different plots, aibika is planted twice a year, spring onions are planted twice a year, chili peppers are planted once a year, tomatoes are planted twice a year, watermelon plants are planted once a year, beans in the fallow subplots are planted twice a year, and beans in the sweet potato fallow subplots are planted once a year.

63. The labour hours required for weeding are assumed to be the same as in Block A. Block required 88 hours per annum for weeding for a 0.20 ha plot. Thus, the 0.10 Block B is assumed to require 44 hours off weeding per annum.

64. During the fallow period, weeding is conducted around the galip nut and tulip trees every two months. The labour hours required for weeding around these trees is a mean of 0.06. This assumes that it will take 3.5 minutes to weed per tree.

65. Labour hours required for harvesting sweet potato, aibika, chili peppers, watermelon, *Gnetum gnemon*, and beans were a mean of 3.5 minutes per plant.

66. Labour hours required for harvesting corn and tomatoes were a mean of 1 minute per plant.

67. Labour hours required for harvesting spring onions were a mean of 0.5 minutes per plant.

68. Labour hours required for harvesting *Canarium indicum* nuts were assumed to be the same as harvesting wet cocoa; 0.46 hours/kg.

69. The model assumes that 50 kina is spent in year zero to purchase tools; bush knife, hoe, and shovel.

A3 Block C Assumptions

Block C is identical to Block A, with one exception. Instead of *Eucalyptus pellita* trees being the shade trees for the cocoa, Block C models the use of *Gliricidia sepium* trees.

70. There are 138 *Gliricidia sepium* trees. These are planted in year zero. The model assumes that any timber collected from the *Gliricidia sepium* trees is for personal use and is not sold in the market.

Appendix B Model assumptions for the Cocoa and Gliricidia agroforestry systems

Appendix B1 Cocoa and Gliricidia agroforestry system – Low Inputs

1. The plot is 1 ha in size.

2. There are 625 cocoa trees. These are planted in year 1 using a 4 x 4 m spacing.

3. The cost of a cocoa seedlings is 4 kina (Wampe and Waviki 2020).

4. Individual cocoa yield per tree is not the same every year. Yield begins in year three, increases every year until it peaks around years 8 – 10, and then declines every year after that. This model utilizes a yield algorithm retrieved from Ryan et al. (2007). This algorithm is for dry annual cocoa produced for an individual tree (kg) in Costa Rica. The algorithm is:

   Yield = exp(-1.1 + ln(a) -0.125a), where a is equal to age of the tree.

5. Modifications were done to the model to more accurately reflect the growing conditions in PNG. According to a previous ACIAR report on small-holder cocoa production, the average annual dry cocoa yield per tree is 1.04 kg (Daniel and Guest 2011). This is 60% higher than the average annual yield presented by Ryan et al. (2007). Hence, the annual yield of each tree was increased by 60%.

6. In PNG, most small-holders sell wet-cocoa and the above algorithm yield is for dry cocoa. A previous ACIAR report on cocoa production in PNG indicates that it takes an average of 2.8kg of wet cocoa to produce 1kg of dry cocoa (Quirke et al. 2007). Hence, the yield per tree was increased by a factor of 2.8 (see figure A1).

7. The mean price for wet bean cocoa is 1.50 kina/kg. (Wampe and Waviki 2020).

8. There are 625 *Gliricidia sepium* trees. These are planted in year zero.

9. Labour hours required for the initial land clearing are a mean of 70 hours/ha (Wampe and Waviki 2020). Land clearing happens in year zero.

10. The labour hours required for planting trees/crops is a mean of 0.06. This assumes that it will take 3.5 minutes per tree/crop. In year zero, every tree/crop is planted except the cocoa trees.

11. The labour hours required for weeding per tree/crop are a mean of 0.04. This assumes that it will take 2.5 minutes to weed around each tree/crop (Wampe and Waviki 2020). The model assumes that weeding occurs every 2 months, until the end of year 2.

12. The labour hours for harvesting cocoa are 0.46 hours/kg of wet bean yield (Curry et al. 2007). Harvesting of cocoa begins in year 3 and goes until year 30.

Appendix B2 Cocoa and Gliricidia agroforestry system – Medium Inputs

The cocoa and Gliricidia medium input model is initially identical to the low input model. The additional inputs are provided below.

1. Cocoa tree pruning in Year 1: This takes a mean of 3 minutes per tree. It only happens once (Wampe and Waviki 2020).

2. Cocoa tree pruning in Year 2: This takes a mean of 2 minutes per tree. It is done three times during year 2 (Wampe and Waviki 2020).

3. Cocoa tree pruning in Year 3+: This takes a mean of 4 minutes per tree. It is done twice a year, every year onward (Wampe and Waviki 2020).

4. Gliricidia pruning: This begins in year 3 and is done twice a year, every year. It takes a mean 7 minutes (Wampe and Waviki 2020).

5. The labour hours required for slash weeding Years 1-2: This takes a mean of 2.5 minutes to weed around each tree (Wampe and Waviki 2020). The model assumes that weeding occurs every 2 months, until the end of year 2. The model assumes that weeding only occurs around the cocoa trees.

6. The labour hours required for slash weeding Years 3+: This takes a mean of 1 minute to weed around each tree (Wampe and Waviki 2020). The model assumes that weeding occurs every 2 months, until the end of Year 3. The model assumes that weeding only occurs around the cocoa trees.

7. The labour hours for harvesting cocoa are 0.46 hours/kg of wet bean yield (Curry et al. 2007). Harvesting of cocoa begins in year 3 and goes until year 30.

Appendix C Model assumptions for the cocoa/banana/eucalyptus agroforestry system

1. The plot is 1 ha in size.
2. There are 625 banana trees planted with a 4 x 4 m spacing in Year zero.
3. The banana trees take one year to yield bunches of bananas. In the first year of growth, the bananas yield a mean 6 bunches. In the second year this declines to 4 bunches. In year three this declines to 2 bunches. After the third harvest, the bananas are replanted.
4. There are 625 cocoa trees. These are planted in year 1 using a 4 x 4 m spacing.
5. At the end of Year 1, 208 of the banana trees are replaced with *Eucalyptus pellita* seedlings, which are planted with a 4 x 4 m spacing. The model assumes that these banana trees only experienced one harvest, at the end of year 1.
6. At the end of Year 2, 208 banana trees are removed to be replaced with *Eucalyptus pellita* seedlings. The model assumes that these banana trees only experienced 2 harvests, at the end of year 1 and the end of year 2.
7. At the end of Year 3, the final 209 banana trees are removed to be replaced with *Eucalyptus pellita* seedlings. The model assumes that these banana trees experienced 3 harvests, at the end of year 1, year 2, and year 3.
8. The cost of a cocoa seedlings is 4 kina (Wampe and Waviki 2020).
9. Individual cocoa yield per tree is not the same every year. Yield begins in year three, increases every year until it peaks around years 8 – 10, and then declines every year after that. This model utilizes a yield algorithm retrieved from Ryan et al. (2007). This algorithm is for dry annual cocoa produced for an individual tree (kg) in Costa Rica. The algorithm is:

   Yield = exp(-1.1 + ln(a) -0.125a), where a is equal to age of the tree.

10. Modifications were made to the model to more accurately reflect the growing conditions in PNG. According to a previous ACIAR report on small-holder cocoa production, the average annual dry cocoa yield per tree is 1.04 kg (Daniel and Guest 2011). This is 60% higher than the average annual yield presented by Ryan et al. (2007). Hence, the annual yield of each tree was increased by 60%.
11. In PNG, most small-holders sell wet-cocoa and the above algorithm yield is for dry cocoa. A previous ACIAR report on cocoa production in PNG indicates that it takes an average of 2.8kg of wet cocoa to produce 1kg of dry cocoa (Quirke et al. 2007). Hence, the yield per tree was increased by a factor of 2.8 (see figure A1).
12. The mean price for wet bean cocoa is 1.50 kina/kg. (Wampe and Waviki 2020).
13. The sales price per banana bunch is 2.00 kina/bunch (Wampe and Waviki 2020).
14. The model assumes that *Eucalyptus pellita* timber that is harvested is for personal use and not sold in the market.
15. Labour hours required for the initial land clearing are a mean of 70 hours/ha (Wampe and Waviki 2020). Land clearing happens in year zero.

16. The labour hours required for planting trees/crops is a mean of 0.06. This assumes that it will take 3.5 minutes per tree.

17. The labour hours required for cutting down and removing the banana trees is a mean of 3 minutes.

8. The labour hours required for weeding per tree/crop are a mean of 0.04. This assumes that it will take 2.5 minutes to weed around each tree/crop (Wampe and Waviki 2020). The model assumes that weeding occurs every 2 months. The model assumes that weeding only occurs up to the end of year 3, around the cocoa and banana trees.

18. The labour hours for harvesting cocoa are 0.46 hours/kg of wet bean yield (Curry et al. 2007). Harvesting of cocoa begins in year 3 and goes until year 30.

19. The labour hours required for harvesting crops is a mean of 0.06. This assumes that it will take 3.5 minutes per individual crop. Bananas are harvested once a year. (Wampe and Waviki 2020).

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Smallholder cocoa agroforestry systems; is increased yield worth the labour and capital inputs?

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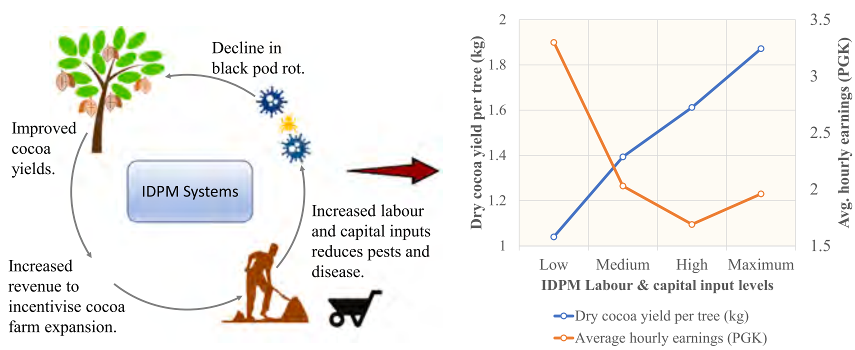
HIGHLIGHTS

- In Papua New Guinea, many smallholder cocoa farmers experience low cocoa yields despite receiving training in pest and disease management systems.
- We hypothesized that the low system uptake may be due to the improved yields not being sufficient to justify the increase in labour and capital.
- We developed discounted cash flow models that incorporated Monte Carlo risk analysis software to evaluate the systems against selected criteria.
- The pest and disease cocoa management systems provided lower mean hourly earnings than the low input cocoa system and this limited adoption.
- Smallholder agroforestry technologies should be evaluated for viability and likelihood of smallholder technology adoption during development.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Smallholder cocoa agroforestry systems provide most of the cocoa produced world-wide and can improve the livelihoods of rural families in the tropics. However, many smallholder cocoa producers experience low cocoa yields due to generally poor management practices, pests, disease, and low soil fertility. In Papua New Guinea, pest and disease management systems have been developed to provide improved yields and revenues, but there has been limited uptake.
OBJECTIVE: We hypothesized that the low uptake of these systems may be due to the improved yields not being sufficient to justify the required increase in labour and capital inputs. Our objective was to assess if the integrated pest and disease management systems were financially viable.
METHODS: Our methods involved developing discounted cash flow models that incorporated Monte Carlo risk analysis software. We populated the models with labour inputs, costs, and revenue data collected in country, and from scientific literature. In addition to net present value, we evaluated the production systems with additional

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criteria we deemed appropriate for assessing the required labour inputs and capital outlays; return on labour; mean labour hours/day; mean annual capital outlays, mean hourly income, and mean annual income.

RESULTS AND CONCLUSIONS: Our results show that under the current cocoa prices being received, all the production systems had a negative net present value, and a mean hourly income that was below the Papua New Guinea minimum wage and less than 1 USD/h. Furthermore, the progressive addition of labour inputs and capital outlays of the pest and disease management systems resulted in mean hourly incomes that are less than currently being received. These decreased hourly earnings may explain the low adoption of these technologies.

SIGNIFICANCE: Financial analyses of new smallholder agroforestry technologies should be used to evaluate the viability and likelihood of smallholder technology adoption. Previous research on cocoa pest and disease management systems failed to account for costs related to labour and capital inputs. Even if farm family labour does not incur a direct cash outflow, it does represent an opportunity cost to farmers. Including additional criteria that measure financial returns to farmers relative to labour and capital requirements should be a part these assessments. These additional criteria can aid in evaluating all the economic thresholds that may impact if and how smallholders will incorporate new agroforestry technologies, which can help improve the success for agriculture-based development projects throughout the global tropics.

1. Introduction

Theobroma cacao L. (cocoa), is a cash crop that is cultivated in the humid lowland tropics around the world. The Food and Agriculture Organization of the United Nations (FAO) estimates that approximately 11.8 million hectares (ha) of cocoa were planted worldwide by 2018 (FAO (Food and Agricultural Organization of the United Nations), 2020). Global cocoa market demand has been forecasted to grow by more than 7% per annum between the years 2019 and 2025 (Voora et al., 2019). Smallholder farmers have been recognized as being responsible for 70% of global cocoa produce (Clay, 2004; Donald, 2004; Voora et al., 2019). Approximately five million rural households rely on cocoa production as a cash crop, which represents between 60% and 90% of their household incomes (Voora et al., 2019). Smallholder cocoa agroforestry systems have been recognized as a high-ranking option for improving the livelihoods of rural families (Rice and Greenburg, 2000; Bentley et al., 2004; Franzen and Bogerhoff, 2007; Cerda et al., 2014).

Despite the forecasted growth in global demand and the potential for improved smallholder livelihoods, it has been projected that global demand will soon outpace supply due to poor smallholder cocoa yields (Voora et al., 2019). The causes of poor and/or declining smallholder cocoa farm yields have been identified throughout the world for more than two decades, including in Papua New Guinea (PNG). These causes include pests, viral and fungal diseases, the loss of soil fertility, and poor shade management (Ghodake et al., 1995; Rice and Greenburg, 2000; Duguma et al., 2001; Krauss and Soberanis, 2001; Lummani and Nailina, 2001; Omuru et al., 2001; Curry et al., 2007; Curry and Koczberski, 2009; Daniel et al., 2011a; Wessel and Quist-Wessel, 2015; and Voora et al., 2019). Previous cocoa research has determined that improved management can improve smallholder cocoa yields and that the increased revenues received would be an incentive for maintaining shade production and improved soil fertility (Franzen and Bogerhoff, 2007; Wessel and Quist-Wessel, 2015).

In PNG, approximately 70% of the population obtains their livelihoods in the agricultural sector (Anon, 2006). Cocoa is PNG's third largest export crop, following palm oil and coffee (Quirke et al., 2007). Cocoa production has transitioned from being largely produced on plantations, to over 80% being produced by smallholders, with family owned cocoa blocks typically being less than five ha in size (Curry et al., 2007; Quirke et al., 2007). In 2018, there were approximately 110 thousand ha of cocoa planted in PNG, an increase of 12% since the year 2000 (FAO (Food and Agricultural Organization of the United Nations), 2020). It has been estimated that there are 151 thousand smallholder households that participate in cocoa production in PNG (DALPNG (Department of Agriculture and Livestock of Papua New Guinea), 2020).

Previous research on smallholder cocoa production in PNG concluded that standard cocoa yields are low due to minimal levels of cocoa block maintenance (Curry et al., 2007; Curry and Koczberski, 2009; Nelson et al., 2009; Daniel et al., 2011a; and Daniel et al., 2011b). This research found that smallholders typically do not prune cocoa trees or shade trees. Limited weed control was also identified as a challenge, and usually only occurred during the first two to three years after tree planting. Weeding was primarily undertaken for harvest access and to promote the growth of intercropped food crops. A consequence of low maintenance was increased pests and diseases, which in turn had a negative impact on cocoa yield. The main pathogen impacting cocoa is *Phytophthora palmivora*, which caused black pod rot (Daniel et al., 2011b). Other pathogens include *Oncobasidium theobromae*, the cause of Vascular Streak disease and *Erythricium salmonicolor*, the cause of pink disease (Keane, 1981; Saul, 1989; McMahon and Purwantara, 2004; Guest, 2007; and Daniel et al., 2011a). Despite a long-term extension program to mitigate these challenges, there has been a low uptake of extension advice (Curry and Koczberski, 2009).

It has been inferred that cocoa production levels and cocoa block maintenance were contingent on key economic production drivers. Godyn (1974), George (1994), Ghodake et al. (1995), and Omuru et al. (2001), reasoned that a commodity price threshold was the key factor in cocoa production and participation. Curry and Koczberski (2009), concluded that while commodity price was important, the most important factor was the quantity or yield of accessible cocoa crop. An attempt to enhance smallholder cocoa production yield through the greater adoption of pest and disease control practices was a recently applied in a PNG research project funded by the Australian Centre for International Agricultural Research (ACIAR) (Daniel et al., 2011a; Daniel et al., 2011b). An 'Integrated Pest and Disease Management (IPDM) system was developed with assistance from the Cocoa Coconut Institute (CCI) in PNG (Daniel et al., 2011a). The IPDM system was outlined in a training manual written by Konam et al. (2011). The IPDM systems had four categories for smallholder cocoa management. The first IDPM system (low inputs) is representative of the existing smallholder cocoa management practices. The remaining three IDPM systems (medium, high, and maximum) require increased activity inputs. It was estimated that incorporating the other three IPDM systems would increase cocoa yield from the low input level by approximately 34% (medium), 55% (high), and 80% (maximum) (Lummani, 2008; Daniel et al., 2011a).

Despite the expected cocoa yield improvements from the IPDM systems, anecdotal evidence suggests that there is still a low uptake of these technologies. We agree with previous researchers in that cocoa commodity price and cocoa yield are both important economic production drivers. However, we also surmise that the labour and capital requirements to achieve the varying levels of cocoa yield will also have an impact on technology uptake. The IPDM training by Konam et al. (2011) discussed the required activities for the four IPDM options but did not provide estimates on the labour requirements or capital costs for implementation. Labour and capital costs represent an important part of any production system and should be considered. Production system analysis is a managerial economic method that utilizes the profit model formula (Wagner, 2012):

Profit = total revenues–total costs, or

Profit = (price*quantity)–(total fixed costs + total variable costs)

We hypothesize that the cause for the low uptake of these technologies was that the improved cocoa yields (quantity) and associated increased revenues were not large enough to offset the increased labour and capital input requirements (costs). Our research objective was to estimate the required labour and capital inputs required for implementing these IDPM technologies and determine if they are financially viable for smallholder cocoa farmers in PNG. Our research questions assessed each IDPM technology system to determine; 1) what is the net present value; 2) what is the return on labour; 3) what are the required mean labour hours per day; 4) what are the required mean annual capital outlays; 5) what is the mean hourly income; and 6) what is the mean annual income?

In the next section of this paper we provide a description of our study site. This is followed by a discussion of our methods used to undertake this analysis, the results, discussion, and key themes, recommendations, and conclusion.

1.1. Our study site

Our study site was near Ramu, within the Ramu/Markham Valley, which exists across the Madang Province and the Morobe Province (Fig. 1). The primary land use is semi-subsistence agriculture, where most families grow their own food, but also participate in local markets with their surplus crops. The area cultivated for cash crops like cocoa per individual farmer family is minimal due to the high costs of genetically improved seedlings and the limited outreach of agricultural extension programs (Baynes et al., 2017). Land tenure follows a complex customary rights system and is passed on within the family. Individual families have user rights over the land, but the land is owned by the clan (Baynes et al., 2017).

1.2. Materials and methods

To test our hypothesis, we undertook an analysis of the production systems for each of the IPDM systems in which we identified all the cost and revenue inputs of these production systems to assess their financial viability. To do this we constructed discounted cash flow (DCF) models for each of the IPDM systems. DCF analysis is a valuation method that estimates the value of an investment today (present value) based on the expected future cash flows (costs and revenues). DCF analysis is based on the 'time value of money' concept; a sum of money is worth more in the present than the same sum of money would be worth in the future. The present value of the expected future cash flows is calculated by using a discount rate. A discount rate is the interest rate used to discount the future cash flows to their present-day value. For our DCF models, we made estimates of all the future costs and revenues for each IPDM system and discounted them to their present value. We evaluated the DCF models with criteria suited for smallholder farmers. Financial criteria are used to assess an investment and evaluate a series of investment projects against each other. A review of the literature on financial analysis of smallholder cocoa production shows that most studies use traditional criteria for DCF analysis; net present value (NPV), benefit-cost (B/C) ratio, internal rate of return (IRR), and land expectation value (LEV) (Ramírez et al., 2001; Obiri et al., 2007; Nunoo and Owusu, 2017). NPV is typically the most common criteria used in financial analysis and represents the sum of all the present values for a particular investment. All the criteria listed above incorporate the time value of money in their valuation. If different investment projects are compared

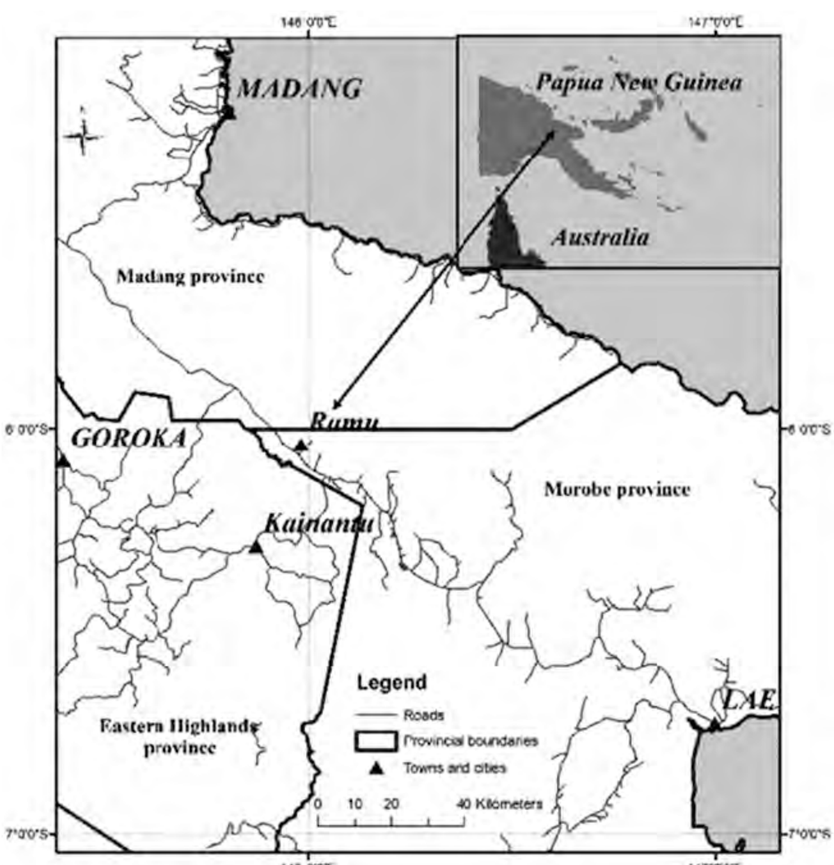

Fig. 1. Location of the study site.

against each other, each of the above criteria will rank their valuation in the same order. We determined that this analysis should also incorporate criteria that evaluates each IPDM system from the viewpoint of the required labour inputs and capital outlays. Hence, we also included the following criteria in our DCF analysis; return on labour; mean labour hours/day; mean annual capital outlays, mean hourly income, and mean annual income. These criteria do not incorporate the time value of money, but we determined that they would be valuable for assessing labour and capital inputs. We utilized a mixed-methods approach to conduct our data collection and DCF analysis. In the following four subsections we discuss; developing the DCF models; the growth and yield assumptions for the cocoa trees; the labour inputs, capital outlays, revenue assumptions, and our data analysis.

1.2.1. *Developing the discounted cash flow models*

We developed four DCF models to simulate the four IPDM cocoa systems. In developing the models, the principles of capital budgeting of investment projects set out by Dayanandra et al. (2002) and Harrison and Herbohn (2017) were followed. The DCF models were constructed in Microsoft Excel software. Monte Carlo risk analysis simulation was used to account for uncertainty associated with 20 of our model variables, which are further discussed in Section 1.2.3, and presented in Table 1. Monte Carlo simulation is a method used for understanding the impact of risk and uncertainty when modelling the probability of different outcomes that cannot easily be predicted due to random variables. Monte Carlo simulation is a type of sensitivity analysis that provides probabilistic results instead of just deterministic results that are associated with a typical sensitivity analysis. The software selected for the Monte Carlo risk analysis was '@RISK', which is a Microsoft Excel Add-in software program produced by the Palisade Corporation. The risk analysis simulation followed methods outlined by Winston (2008) in which all cash flow variables determined to have values with inherent uncertainty were assigned triangular distributions; minimum; most likely; and maximum values. The DCF models were designed to randomly select a value within the assigned distribution range of each uncertain variable for each iteration of the simulation. The number of iterations selected for the Monte Carlo risk simulations was 10,000.

The initial criteria used to evaluate the DCF models was NPV, IRR, return on labour, mean labour hours/day, mean annual capital outlays. Most smallholder cocoa producers in PNG rely on family labour and do not use outside paid labour sources. This family labour does not incur a direct cash outflow but does represent an opportunity cost of lost earning capacity. As such, we decided to use the current minimum wage in PNG of 3.5 PGK/h ($1.03/h expressed in US dollars based on an exchange rate of 0.294) as a 'shadow' price to capture the value of family labour. Return on labour was calculated by dividing the sum of the total earnings by the sum of the total labour hours worked during the simulated 30 years. The mean labour hours/day criteria calculation assumed that cocoa farmers would work 240 days per year. The mean annual capital outlays were calculated by averaging all the capital outlays during years one through 30. We included a second category of criteria to evaluate the DCF models; mean hourly income and mean annual income. For these secondary criteria, we removed the shadow price we previously placed on family labour. This was done to provide an estimate of the income that individuals would receive if they implemented these IPDM systems. These additional criteria also do not incorporate the time value of money. Mean hourly income was calculated by dividing the sum of the total earnings by the sum of the total labour hours worked during the simulated 30 years, after removing the labour shadow price. Mean annual income was calculated by multiplying the mean hourly earnings by mean labour hours per day and by 240 days per year.

All the models utilized a real risk-free discount rate and constant 2020 PNG Kina (PGK) prices were used to remove inflation from the analysis. The real risk-free discount rate was determined by taking the Bank of PNG's (BPNG) long-term 10-year bond yield (11.01%), and the

Table 1
IDPM system model assumptions used in the DCF Monte Carlo simulation analysis.

Description of input/outlay	Unit	Occurrence	Certain variable	Uncertain variable ranges		
				Low	Median	High
Low inputs:						
Cocoa revenues	PGK/kg.	Years 3–30		1.3	1.5	2
Labour inputs						
Land clearing	Hours/ha	Year 0		40	70	100
Tree planting	Min/tree	Year 0		2	3.5	5
Weeding	Min/tree	Years 1–2		2	2.5	3
Harvesting	Hours/kg	Years 3–30	0.48			
Capital outlays						
Cocoa seedlings (625)	PGK/seedling	Year 0	4			
Gliricidia seedlings (625)	PGK/seedling	Year 0	0			
Medium inputs (additional):						
Labour inputs						
Cocoa tree pruning	Min/tree	Year 1		2	3	4
Cocoa tree pruning	Min/tree	Year 2		1	2	3
Cocoa tree pruning	Min/tree	Years 3–30		2	4	5
Gliricidia tree pruning	Min/tree	Years 3–30		3	7	10
Weeding	Min/tree	Years 3–30		0.5	1	1.5
Black pod removal	Min/tree	Years 3–30		2	2.5	3
Black pod burial	Hours	Years 3–30		2	3	4
High inputs (additional)						
Labour inputs						
Urea fertilizer	Min/tree	Years 0–30		0.3	0.6	1
NPK fertilizer	Min/tree	Years 0–30		0.3	0.6	1
Lambda-cyhalothrin	Min/tree	Years 3–30		2	4	6
Infection rate	Percent	Years 3–30		10	15	30
Capital outlays						
Urea fertilizer	PGK/g	Years 0–30	0.004			
NPK fertilizer	PGK/g	Years 0–30	0.004			
Lambda-cyhalothrin	PGK/ml.	Years 3–30	0.03			
Maximum inputs (additional)						
Labour inputs						
Glyphosate weed killer[a]	Min/tree	Years 0–30		0.16	0.33	0.5
Canker mixture	Min/tree	Years 3–30		1	4	8
Pirimiphos-methyl	Min/tree	Years 3–30		1	5	10
Infection rate	Percent	Years 3–30		10	15	30
Capital outlays						
Glyphosate weed killer	PGK/ml.	Years 0–30	0.02			
Canker mixture	PGK	Years 3–30	4.99			
Canker mix. Application	Trees	Years 3–30		10	15	20

(*continued on next page*)

Table 1 (*continued*)

Description of input/outlay	Unit	Occurrence	Certain variable	Uncertain variable ranges		
				Low	Median	High
Pirimiphos-methyl	PGK/ ml.	Years 3–30	0.03			

Sources: All the uncertain variable range values, seedling costs, and capital outlays were collected during interviews with key informants. The cocoa labour harvesting input was collected from Curry et al. (2007).
Note: Additional information of the IDPM inputs is provided in Appendix.
[a] The glyphosate weed killer labour input replaced all other weeding-based labour inputs.

average annual inflation rate in PNG for the last 10 years (5.19%) (BPNG (Bank of Papua New Guinea), 2020). These two rates were incorporated into the Fisher equation (Eq. (1)) to identify the risk-free, inflation-free discount rate, which was 5.53%.

$$R = \left[\left(\frac{1+r}{1+i}\right) - 1\right] \textit{ where}$$

$$R = \textit{real risk free discount rate}$$

$$r = \textit{discount rate}$$

$$i = \textit{inflation rate} \tag{1}$$

1.2.2. Growth and yield assumptions for the cocoa trees

Smallholder cocoa producers in PNG typically use *Gliricidia sepium* (gliricidia) for shade trees. The common spacing measurements for both species are 4 × 4 m., with the gliricidia trees planted between the cocoa trees. Cocoa trees typically start bearing fruit when they are two to three years old. The main harvest occurs from October to January (wet season) and a smaller harvest occurs between April and July (dry season) (Konam et al., 2011). Growth and yield data for the cocoa trees was collected from peer-reviewed literature, final reports from previous research projects in PNG conducted by ACIAR, and other published reports. A review of the literature shows that cocoa yield per tree in PNG is not the same every year. Yield typically begins in year three, increases every year until it peaks around years eight to ten, and then declines every year after that (Curry et al., 2007). We utilized a yield algorithm retrieved from Ryan et al. (2007). This algorithm is for dry annual cocoa produced for an individual tree (kg) in Costa Rica (Eq. (2)).

$$Y = e^{[-1.1+ln(a)-0.125a]} \textit{ where}$$

$$Y = \textit{cocoa tree yield}$$

$$a = \textit{cocoa tree age} \tag{2}$$

Eq. (2) was modified to more accurately reflect the growing conditions in PNG. According to previous research, the average annual dry cocoa yield per tree is 1.04 kg (Daniel et al., 2011a). This is 60% higher than the average annual yield presented by Ryan et al. (2007). Hence, the annual yield was increased by 60%. In addition, we wanted to model the wet cocoa yield per tree, while the algorithm by Ryan et al. (2007) is for dry yield. And to do so we applied a conversion factor of 2.8 based on previous research, which indicates that it takes an average of 2.8 kg of wet cocoa to produce 1 kg of dry cocoa (Quirke et al., 2007). Our model assumed a planting design with a spacing of four by four metres between trees, resulting in 625 cocoa trees per ha. The cocoa yield algorithm retrieved from Ryan et al. (2007), utilized a timeline of 50 years. Cocoa farmers within our study site explained to us that a 30-year timeline more accurately reflected smallholder cocoa management at our study site, which is what we selected. The base system reflected the current (low input) production system. Research on the IPDM system indicated that the (low input) yields could be increased by 34% with (medium level inputs), 55% with (high level inputs), and 80% with (maximum level inputs) (Lummani, 2008; Daniel et al., 2011a) (See Fig. 2).

1.2.3. Labour inputs, capital outlays, and revenues

Data on labour inputs, capital outlays, and revenues was collected through interviews with key informants within our study site. Interviews were conducted by the first three authors and varied between 30 min and one hour. Seven interviews were undertaken in total and included employees of Ramu Agri-Industries Ltd. (RAIL), an employee of the Morobe Province Cocoa Board, and four smallholder cocoa producers that were recognized as being expert cocoa producers. The RAIL employees work with small holder communities in the Ramu-Markham Valley by providing tree seedling nursery development and agroforestry training, which has a strong focus on cocoa. The Morobe Province Cocoa Board manages the provincial government cocoa nursery, conducts cocoa management training with smallholder farmers, and collects and disseminates annual cocoa production data for the entire Morobe Province. The smallholder cocoa farmers were identified upon recommendations from the RAIL and Morobe Province Cocoa Board employees, as being expert cocoa producers. These smallholder cocoa producers began as subsistence farmers with minimal cocoa trees and have advanced their operations to the point where cocoa production represents their primary livelihood activity. These four expert cocoa farmers were the only farmers within our study site that were able to provide hands-on knowledge of the labour requirements for implementing the IDPM activities.

An interview protocol was designed to ascertain the required hours of labour inputs and the capital outlays of the IPDM cocoa management systems (Konam et al., 2011). Estimating labour inputs can be a challenge because there will likely be variations between farmers in the time required to complete the different labour activities. The variability of these labour activities creates an inherent uncertainty for these model variables. Hence, we asked key informants to provide us with an estimated range of time (low, median, and high) required for completing each labour activity. For each iteration of the DCF models (10,000 total iterations), the Monte Carlo risk analysis software randomly selected a value from within the specified range of each uncertain variable. For capital outlays involving the purchase of fertilizer, insecticides, and canker treatments, we collected costs from local retailers near the study site. The quantity of fertilizers, insecticides, and canker treatments applied per ha was based on recommended application rates (Konam et al., 2011). These IPDM systems build upon each other, with each level incorporating additional labour inputs and/or capital outlays. We have summarized how we incorporated these systems into our DCF models below:

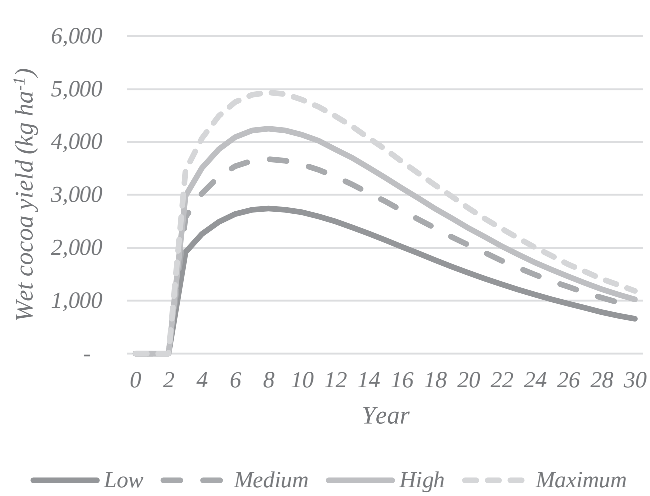

Fig. 2. Expected annual wet cocoa yield by IPDM systems.

1) (Low input/current practice): There are minimal labour inputs for the low input IPDM system. The land is cleared and planted with cocoa seedlings and gliricidia stems during year zero. Ring weeding with bush knives around the cocoa trees occurs during the first two years (six times/year) but ceases after that. Cocoa harvesting begins in year three and continues to year 30.
2) (Medium inputs): Additional labour activities are incorporated; cocoa tree pruning; gliricidia tree pruning; continuous annual weeding; and the removal and burial of black cocoa pods. The five components of cocoa tree pruning are; formation pruning; chupon or water shoot pruning; sanitation pruning; structural pruning; and yield-simulating pruning. Gliricidia tree pruning is done to allow the cocoa trees to receive about 75% of full sunlight to promote healthy growth while minimizing pests, disease, and weed growth. Continuous annual weeding is done to reduce cocoa competition for water and soil nutrients, and to minimize the spread of pests and disease. Black pod removal and burial is done to reduce the spread of inoculum and incidence of disease.
3) (High inputs): Urea fertilizers and Nitrogen/Phosphorus/Potassium (NPK) fertilizers are applied to the cocoa trees twice/year for improved tree health. Lambda-cyhalothrin is applied as an insecticide to the cocoa trees to combat cocoa pod borer (*Conopomorpha cramerella*) a moth that lays eggs on the surface of the pods. Monthly target pod spraying is applied to infected pods and the undersides of the branches.
4) Maximum inputs): Additional chemical applications are applied; chemical weed killer; canker mixture treatment; and additional insecticide spraying. Glyphosate is used as a weed killer and is sprayed around each cocoa tree four times/year during every year of production. This activity replaces all manual weeding. A canker mixture containing cuprous oxide (60 g), dichlorvos (30 ml.), white oil (30 ml.), and water (940 ml.) is applied to infected canker spots on the trunks and branches of cocoa trees twice/year. Additional insecticide spraying is done for insect vector control. Pirimiphos-methyl is applied as an insecticide twice/year to all woody pod-bearing branches, any ant-tent pathways, and piles of infected pod husks.

We supplemented interview data with labour estimates published from previous cocoa research in PNG by Curry et al. (2007). We shared all our collected estimates on labour inputs, capital outlays, and revenues with the RAIL and Morobe Province Cocoa Board employees, and they confirmed that the estimates we obtained were appropriate. These estimates are provided in Table 1. The data inputs or outlays for the specified IPDM level are generally incremental, with each additional IDPM level incorporating all the inputs/outlays from the previous levels. The one exception is that in the maximum input level weeds are killed with insecticide spraying, which replaces the need for manual weeding.

Key informants estimated that black pod removal would take between 2 and 3 min per tree and be conducted 24 times per year, as per recommendations from Konam et al. (2011) (see appendix). This estimate was based on the expert opinions of key informants since the most smallholders do not implement this activity and a time and motion study of this activity has never been conducted. We surmised that the time required for black pod removal would decline when the additional activities of the IDPM systems were implemented because pests/disease in the cocoa blocks would be reduced. To incorporate this into our model, we reduced the time required for black pod removal per tree and black pod burial by the same proportion that the cocoa yield was increased for each consecutive IDPM system; by 34% with (medium level inputs), 55% with (high level inputs), and 80% with (maximum level inputs) (Lummani, 2008; Daniel et al., 2011a).

1.2.4. Data analysis

Descriptive statistics (mean, minimum, maximum, and standard deviation) were calculated for the DCF evaluation criteria produced from the Monte Carlo simulation for each of the four IPDM systems. In addition, we calculated the range of values for each DCF criteria, for all four IDPM systems, that have a 90% probability of occurring.

While conducting the analysis, we found that all four IDPM systems had a negative mean NPV. Furthermore, we found that it was not possible to calculate the mean IRR of each IPDM system due to there being consistent negative annual cash flows during every year, for each of the systems. IRR is a mathematical function of the root of a polynomial equation; if the net cash flow does not change sign at least once it is not possible to calculate a result that makes economic sense (Wagner, 2012). We decided to conduct a break-even analysis to see what it would take for these systems to break-even in terms of the cocoa wet bean price. To do this, we used Microsoft Excel's 'goal seek' function. This function is a software feature that essentially uses a trial and error approach to back-solve the problem by plugging in guesses until it arrives at the answer. To find the break-even price we had the goal seek function set the NPV value to zero by changing the wet bean price (PGK/kg). It should be noted that the excel 'goal seek' function is not compatible with the Monte Carlo simulation software. When we conducted the break-even analysis, all the variables that we had identified as being inherently uncertain were set to their median range value.

The Monte Carlo @Risk software provided a sensitivity analysis report that identified the uncertain variables in the model that had the largest impact on the range of the mean of the dependent variables. In our results, we present the top three uncertain variables that had the greatest impact on the range mean NPV for each IPDM system. While conducting the analysis, we found that the wet bean cocoa price/kg was the variable that had the greatest impact on the range of mean NPV. Since we also wanted to compare the impact of wet bean cocoa price to the impact of the combined labour requirements on the range of mean NPV, we summed all the labour requirements with uncertainty that we used in our model to create an additional discrete variable (total labour requirements) that was assessed by the Monte Carlo @Risk software sensitivity analysis.

2. Results

Table 2 presents descriptive statistics of our DCF evaluation for the initial criteria of the four IPDM cocoa management systems. Table 3 presents descriptive statistics for the second category of criteria (labour shadow price removed). Table 4 presents the range of values for each DCF criteria, for all four IDPM systems, that have a 90% probability of occurring (labour shadow price included). Table 5 presents the mean annual cash flows (years 1–30) of the four IPDM cocoa systems (labour shadow price included).

All four of the IPDM systems had a negative mean NPV, indicating that each system provided a mean return on labour that was less than the PNG minimum wage (our labour shadow price). As can be seen in Table 3, the low input system had the highest mean hourly income and the lowest mean annual income. The low input system had a mean labour hours/day of 3.2 per ha. This increased by 122% for the medium input system, 141% for the high input system, and 141% for the maximum input system. While the medium, high, and maximum IPDM systems provide a larger annual income relative to the low input system, the hourly earnings are consistently less (See Fig. 3). Thus, pursuing these higher intensity management systems would require a farmer to forego applying labour hours to other livelihood strategies, or residing in a household that had a larger pool of labour. The low and medium input systems did not have any annual capital outlays (years 1–30). The mean annual capital outlays for the high and maximum input systems were 921 and 1063 PGK respectively (equivalent to $272 and $314) (BPNG (Bank of Papua New Guinea), 2020), an amount that would be difficult for most smallholders to provide.Fig. 3

The break-even analysis for the low, medium, high, and maximum input systems, indicated that cocoa prices of 1.77, 2.57, 2.83, and 2.50 PGK/kg of wet bean respectively are required. The USD equivalent of

Table 2
Descriptive statistics of DCF criteria of the four IPDM systems.

Inputs	Criteria	Mean	Min	Max	Std. Dev.
Low	NPV (PGK)	-4365	−12,244	5976	3856
	Return on labour (PGK)	-0.20	−0.84	0.64	0.31
	Mean labour hours per day	3.2	3.2	3.2	0.0
	Mean annual capital outlays	–	–	–	–
Medium	NPV (PGK)	−37,426	−52,077	−37,426	5382
	Return on labour (PGK)	−1.47	−1.93	−0.85	0.18
	Mean labour hours per day	7.1	6.4	7.7	0.1
	Mean annual capital outlays	–	–	–	–
High	NPV (PGK)	−49,274	−66,450	−28,646	6402
	Return on labour (PGK)	−1.81	−2.80	−1.15	0.20
	Mean labour hours per day	7.7	7.0	8.4	0.2
	Mean annual capital outlays	921	913	933	4
Maximum	NPV (PGK)	−42,283	−62,664	−20,494	7300
	Return on labour (PGK)	−1.54	−2.09	−0.81	0.24
	Mean labour hours per day	7.7	7.2	8.5	0.2
	Mean annual capital outlays	1063	1011	1167	24

Note: The values in this table incorporate an opportunity cost for labour. We used a shadow price of 3.50 PGK/h, which is the current minimum wage.

Table 3
Descriptive statistics of additional DCF criteria of the four IPDM systems.

Inputs	Criteria	Mean	Min	Max	Std. Dev.
Low	Mean hourly income (PGK)	3.30	2.66	4.14	0.37
Medium		2.03	1.57	2.65	0.27
High		1.69	0.70	2.35	0.41
Maximum		1.96	1.41	2.69	0.32
Low	Mean annual income (PGK)	2534	2043	3180	161
Medium		3459	2412	4897	360
High		3123	1176	4738	404
Maximum		3622	2436	5488	466

Note: The values in this table do not include an opportunity cost for labour.

Table 4
DCF criteria range of values with 90% probability of occurrence.

Inputs	Criteria	Low end	High end
Low	NPV (PGK)	−10,037	2644
	Return on labour (PGK)	−0.66	0.37
	Mean labour hours per day	3.2	3.2
	Mean annual capital outlays	–	–
Medium	NPV (PGK)	−45,947	−27,555
	Return on labour (PGK)	−1.77	−1.12
	Mean labour hours per day	6.8	7.4
	Mean annual capital outlays	–	–
High	NPV (PGK)	−59,265	−38,226
	Return on labour (PGK)	−2.13	−1.45
	Mean labour hours per day	7.3	8.0
	Mean annual capital outlays	927	955
Maximum	NPV (PGK)	−53,189	−29,127
	Return on labour (PGK)	−1.90	−1.10
	Mean labour hours per day	7.4	8.0
	Mean annual capital outlays	1029	1107

these break-even prices was; $0.52; $0.76; $0.83; and $0.74/kg of wet bean. There was a progressive increase in the break-even price for each IDPM system until the maximum-input system. The break-even analysis

Table 5
Mean annual cash flows of the four IPDM systems for years 1–30.

	Low inputs	Median inputs	High inputs	Maximum inputs
Cocoa revenues (PGK)	2717	3642	4213	4892
Labour costs (PGK)				
Weeding (manual)	36	241	241	–
Harvesting cocoa	2741	3673	4248	4933
Cocoa tree pruning		260	260	260
Gliricidia tree pruning		454	454	454
Black pod removal/ burial		1610	1098	488
Urea application			48	48
NPK application			48	48
Karate insecticide application			321	321
Weeding (chemical)				48
Canker mixture application				58
Insect vector application				71
Capital outlays (PGK)				
Urea			274	274
NPK			604	604
Karate insecticide			39	39
Roundup weed killer				50
Canker mixture				78
Insect vector insecticide				13
Net cash flow (PGK)	−60	−2596	−3422	−2895

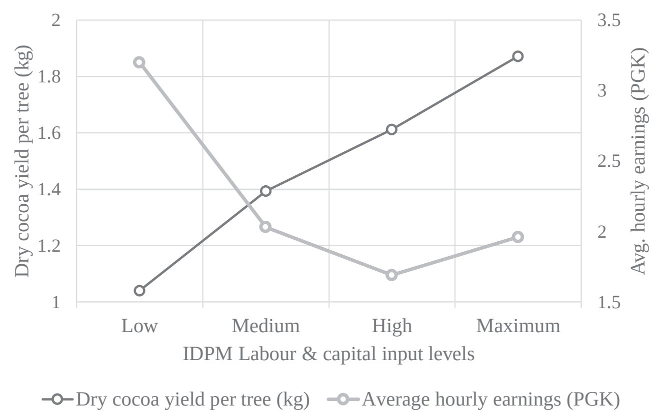

Fig. 3. Cocoa yield versus average hourly earnings by IPDM systems.

highlights how quickly all the IPDM systems could become financially viable with a change in market price.

The @Risk software sensitivity analysis report stated that the wet bean cocoa price/kg had the greatest impact on the range of mean NPV for all four IDPM systems. Changes in this variable resulted in the range of mean NPV fluctuating by thousands of PGK for each IPDM system; low input, 12,997 PGK ($3834); medium input, 13,033 PGK ($3845); high input, 20,091 PGK ($5927); and maximum input, 23,339 PGK ($6885). For the medium input system, the variables that had the second and third greatest impact on the range of mean NPV were; black pod removal, 5327 PGK ($1571); and gliricidia pruning labour hours, 4718 PGK ($1392). For the high input system, the variables that had the second and third highest impact on mean NPV were; gliricidia pruning labour hours, 4624 PGK ($1364), and black pod removal, 3493 PGK ($1030). For the maximum input system, the variables that had the second and third highest impact on mean NPV were gliricidia pruning labour hours, 4415 PGK ($1302), and Pirimiphos-methyl insecticide application labour hours, 3306 PGK ($975).

We also used the data from the @Risk software sensitivity analysis report to identify how the total sum of labour inputs impacted the mean NPV, relative to the wet bean cocoa price/kg. The sum of labour inputs for the low input system impacted the range of mean NPV by 24,003 PGK ($7081). The sum of labour inputs for the medium input system impacted the range of mean NPV by 17,382 PGK ($5128). The sum of labour inputs for the high input system impacted the range of mean NPV by 24,778 PGK ($7310). The sum of labour inputs for the maximum input system impacted the range of mean NPV by 25,707 PGK ($7584).

3. Discussion

We found that under the current market price for wet bean cocoa in PNG, all the IPDM systems had a negative NPV and negative mean annual cash flows during years 1–30. Each of the IPDM systems are essentially providing an hourly income that is below PNG's minimum wage, which is 3.5 PGK/h ($1.03/h). Our results show that the incremental labour costs and capital outlays required to increase the cocoa yield outweigh the additional revenues received. While it is unlikely that smallholders have conducted a rigorous cash flow analysis of these cocoa systems, it is possible that they have an inherent understanding of the labour requirements for implementing these activities and can judge if the market prices they would receive for their labour are higher than could be received for other livelihood strategies. In this analysis, it may be that smallholders are choosing not to adopt these technologies because they perceive (justifiably) the financial returns to not justify the means.

Our @Risk software sensitivity analysis report stated that the wet bean cocoa price/kg was the variable that had the greatest impact on the range of mean NPV for all four IDPM systems. This result is in line with the inferences of Godyn (1974), George (1994), Ghodake et al. (1995), and Omuru et al. (2001), who reasoned that a commodity price threshold was the key factor in cocoa production and participation. However, the @Risk software sensitivity analysis report indicated that the combined cost of the labour inputs had a greater impact on the range of mean NPV relative to the wet bean price/kg, across all the IPDM systems. This demonstrates that the labour inputs and capital outlays are important factors to consider when introducing new agroforestry technologies to smallholders. Our break-even analysis has demonstrated how these three types of thresholds are intertwined and need be viewed together rather than separately. By assessing all the financial variables of a production system, it may be easier to estimate where all the economic thresholds are, which can be crucial for trying to understand if smallholders will be willing to adopt new agroforestry technologies.

Our research has shown that modelling agroforestry production systems from the perspective of the required labour inputs and capital outlays can be a valuable tool for agroforestry extension providers and agroforestry-based projects. The inclusion of return on labour, mean labour hours/day, mean annual capital outlays, mean hourly income, and mean annual income as evaluation criteria provide an additional metric for assessing if the applied technologies are appropriate for a specific situation. For example, our break-even analysis demonstrated that a cocoa price increase of approximately 1–2 PGK/kg of wet bean ($0.29 - $0.58/kg of wet bean), could result in all four IPDM systems becoming viable from the viewpoint of a financial criteria, such as NPV. However, the increased labour inputs required to achieve the higher cocoa yields may not be feasible for smaller households that are constrained by the amount of labour that they can devote to individual livelihood strategies. This has been recognized as one of the reasons for low cocoa production in PNG (Ghodake et al., 1995; Lummani and Nailina, 2001; Omuru et al., 2001; Curry et al., 2007, and Daniel et al., 2011a). During our interviews with key informants, we were told that most smallholders employ multiple livelihood strategies to hedge against the risk of one and/or multiple strategies failing to produce the desired results. It was stated that families are constrained by the number of hours they can apply to each strategy, which is typically based on the size of the household. In addition, many of these smallholders live near or below the poverty line and are not able to easily afford the capital requirements for certain livelihood strategies. It may be that many of these smallholders would not be able to provide the capital requirements for the high and maximum IPDM systems on an annual basis. Even if the increased revenues from an applied technology could be earmarked for future capital outlays, only 15% of the population in PNG has a bank account (Bakani, 2018), making it difficult for smallholders to safely store cash.

The development of forecasted mean annual cash flows (Table 3) is also a tool that can be advantageous for assessing different agroforestry systems. In this analysis, it allowed us to see how the different activities impacted costs for each of the IPDM systems. Viewing labour inputs and capital outlays from this perspective made it possible to evaluate if certain input activities provided greater cost savings than others. For example, the maximum input system utilized chemical spray weeding as a replacement for manual weeding. This resulted in a mean annual cost savings of 193 PGK/ha ($57/ha), relative to the medium and high input systems. An additional benefit for assessing the forecasted mean annual cash flows is to identify opportunities for decreasing costs of individual labour and capital outlay inputs. For example, we found that after cocoa harvesting and black pod removal/burial, the labour activity with the a continuously high-ranking cost was gliricidia pruning. This begs the question of; would a different tree species that did not require pruning be more appropriate as a shade tree for cocoa agroforestry systems in PNG? During our research, we identified cocoa farmers that had recently began to use *Eucalyptus pellita* as shade trees due to the species' self-pruning characteristics. This same process could also be applied to the capital outlays like fertilizer (NPK and urea) to see if lower cost alternatives exist that could still provide comparative increases in cocoa yield. We believe that smallholder cocoa production in PNG would benefit from incremental analysis research of the labour inputs and capital outlays discussed in this paper. The inclusion of these criteria would also allow agroforestry extension providers and reforestation project leaders to provide recommendations that are more tailored to specific households and/or communities.

Three key themes emerged from our analysis. Based on these we provide several recommendations for agriculture extension personnel and project managers in the development of future agroforestry systems for smallholders:

1) A financial analysis of the proposed agroforestry production system should be conducted before making recommendations or implementing operations

Future smallholder agroforestry technology systems will have a better chance of achieving financial viability and being adopted by smallholders if a rigorous analysis of the required labour inputs, capital outlays, and forecasted market prices is conducted. Previous research has shown that most smallholders in PNG have limited knowledge of commodity market values and market demand beyond their local environment (Scudder et al., 2019), resulting in slow transitions in labour from one activity to another. In addition, technology adoption will likely hinge on witnessing others (e.g. early adopters) benefiting from the implementation of these cocoa management strategies. Social learning through viewing the success/failures of early adopters has been recognized as being important process for the diffusion of new agricultural technologies by smallholder farmers in Ghana (Conley and Udry, 2010). To improve the future success rate of early adopters of new agricultural technologies, we recommend that extension personnel/project managers conduct financial analyses to identify the key break-even thresholds of the proposed agroforestry system. In addition, we suggest that an incremental analysis of these inputs be undertaken to identify which inputs are the most important for increasing agroforestry yields and determining which inputs provide the greatest return relative to cost.

2) PNG smallholders implementing cocoa agroforestry systems are typically receiving a financial return that is below minimum wage

The PNG Department of Agriculture and Livestock has the stated goal of increasing cocoa production for the betterment of smallholder livelihoods (DALPNG (Department of Agriculture and Livestock of Papua New Guinea), 2020). Increased smallholder cocoa production and adoption of agroforestry technologies is more likely to occur if smallholders receive a market price that allows them to achieve an hourly income that is at least equivalent to the minimum wage. In 2020, the average international market price for cocoa was $2.40/dry bean/kg (Statista, 2021). The farmgate price being received by smallholders at our study site was $0.38 - $0.59/kg of wet bean, which represents 15–25% of the international market price. We recommend that further research of the cocoa supply chain in PNG be conducted to determine if smallholders are receiving an equitable share of market value, and to identify opportunities for reducing costs between the various value-add stages in the supply chain.

3) Using alternative cocoa shade tree species may improve return on labour

Our analysis found that pruning maintenance of the gliricidia trees was one of the management activities with the highest labour costs. Alternative shade trees, such as *E. pellita* may require fewer labour inputs. There is a gap in the literature regarding how cocoa yield will change when a legume tree species is replaced by a eucalypt species to act as a shade tree. We recommend that additional research be undertaken on the use of *E. pellita* and other species (which also provide timber) as a shade tree for cocoa agroforestry systems to determine if this is an applicable strategy for reducing labour inputs, and to identify if there is an impact to cocoa yields.

In every modelling analysis there are always limitations. It has been recognized that estimating agroforestry labour inputs can be especially challenging (Atangana et al., 2014). The variation in labour inputs will fluctuate between individuals due to experience, ability, age, and sex. Furthermore, it is likely that labour inputs will vary by geographic locations due to cultural differences and/or modifications of the agroforestry system due to local conditions. At our study site, labour time measurements for smallholder cocoa management activities were not available. This type of data analysis, commonly referred to as a time-and-motion study is typically conducted for industrial scale management activities. We did not have the available resources for conducting a time-and-motion study for our labour inputs, and thus were limited to estimates gathered during interviews with key informants. Future agroforestry assessments can be improved with more precise labour time estimates. In addition to these general limitations, we have identified four limitations that are specific to our model:

1) The cocoa yield estimates are not based on PNG specific data

Research by Curry et al. (2007), found that cocoa yield in PNG is not the same every year; it typically begins in years 2–3, peaks around years 9–10, and then declines every year after that. Unfortunately, we were not able to find any data that provides a mathematical description of how cocoa yields in PNG change annually. We utilized a cocoa yield algorithm produced by Ryan et al. (2007), that was based on cocoa yield measurements in Costa Rica. We modified this algorithm with cocoa yield per tree measurements in PNG (Daniel et al., 2011a), and a wet bean to dry bean ratio in PNG (Quirke et al., 2007).

2) The increased cocoa yields received for implementing the IPDM systems are fixed values that do not incorporate variations that would likely occur

These values were collected from Lummani (2008) and Daniel et al. (2011a). Unfortunately, only the mean values were provided without any data on standard deviation. Because of this, we had to insert these values as fixed variables into the models, rather than a range of values like we were able to do for labour variables that had inherent uncertainty. Using fixed values does not reflect variations in yield that would realistically occur. Our results from the Monte Carlo simulation were able to demonstrate how the range of values for the wet bean cocoa price and labour inputs impacted range of mean NPV, but we could not compare this to the changes in yield per IPDM system.

3) The labour for cocoa harvesting (hours/kg of wet bean) is a fixed value that does not incorporate variations that would likely occur

This value was collected from Curry et al. (2007). This input also did not have any data on standard deviation, resulting in it being a fixed variable within our model. Of the 21 labour variables in our model, this was the only one that was fixed. As a result, the growth in labour hours for harvesting is perfectly correlated with the growth in yield between IPDM systems.

4) The model assumes that the labour for black pod removal will decline by the same ratio as the increase in cocoa yield, with each progression of the IPDM systems

The labour assumption for black pod removal under existing conditions was; 2–3 min per tree. This was based on our interviews with key informants. With the progression to the medium, high, and maximum IDPM systems, we assumed that the black pod occurrence would decline, and the required labour hours for black pod removal per tree would also decline. Unfortunately, we were not able to find any data that we could use to input how black pod removal labour would change as the IPDM systems progressed. Our model assumes that black pod removal labour would decline by the same ratio as the increase in cocoa yield values we collected from Lummani (2008) and Daniel et al. (2011a). We understand that there will not be a perfect correlation between increased cocoa yield and black pod labour decline but could not find any data in the scientific literature that we could use as an alternative.

4. Conclusion

Our research objective was to estimate the required labour and capital inputs for implementing these IDPM technologies and determine if they are financially viable for smallholder cocoa farmers in PNG. We found that with the current cocoa prices, smallholders are receiving an equivalent hourly earnings that is less than the minimum wage in PNG. In addition, the progressive addition of labour inputs and capital outlays of the IPDM systems results in hourly earnings that are less than the low input, or current system being practiced by smallholders. These decreased hourly earnings may explain the low adoption of these technologies. We determined that conducting a financial analysis of agroforestry production systems is a valuable assessment and should be included when evaluating the likelihood of smallholder participation. In addition, we believe that the additional evaluation criteria used in this analysis (return on labour, mean labour hours/day, mean annual capital outlays, mean hourly earnings, and mean annual earnings) should be incorporated in other future evaluations of agroforestry systems to view the management activity requirements from the view of labour and capital input costs.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Appendix

Low IDPM inputs:

1) In years 1–2, weeding around cocoa trees occurs six times per year.
2) The source for the cocoa harvesting hours/kg. is: Curry et al. (2007).

Medium IDPM inputs:

1) In year 1 and years 3–30, cocoa tree pruning is conducted twice per year.
2) In year 2, cocoa tree pruning is conducted three times per year.
3) In years 3–30, weeding around the cocoa trees occurs six times per year.
4) In years 3–30, cocoa black pod removal occurs 24 times per year. The removals occur weekly, during the wet harvest season (October–January), and bi-weekly during the dry harvest season (April–July) (Konam et al., 2011).

High IDPM inputs:

1) In years 0–30, urea fertilizer is applied to each cocoa tree twice per year.
2) In years 0–30, NPK fertilizer is applied to each cocoa tree twice per year.
3) In years 3–30, Karate insecticide is applied to trees with infected pods (cocoa pod borer) on a monthly basis.
4) The infection rate refers to the percentage of the cocoa plantation needing to be sprayed with Karate insecticide.
5) Urea fertilizer application is 5 g/tree for years 0–2 (twice/year), and 50 g/tree for years 3–30 (twice per year).
6) NPK fertilizer application is 15 g/tree for years 0–2 (twice/year), and 120 g/tree for years 3–30 (twice per year).
7) Karate insecticide is applied in a water solution. We assumed an application of 1 ml. of insecticide/tree.
8) The time requirements for black pod removal and black pod burial presented in Table 1 were reduced by 55% to reflect the positive effects of the IDPM activities.

Maximum IDPM inputs:

1) In years 1–30, Roundup weed killer is applied around each cocoa tree four times per year. This labour input replaced all other weeding-based inputs.
2) In years 3–30, the canker mixture is applied twice per year.
3) In years 3–30, the insect vector insecticide is applied to all infected cocoa trees twice per year.
4) The infection rate refers to the percentage of the cocoa plantation needing canker mixture and insecticide.
5) Roundup weed killer is applied in a water solution that requires 1 ml. of roundup/tree.
6) Canker mixture is a combination of Copper Nodox (60 g), Nuvan (30 ml.), and White oil (30 ml.) (See Konam et al., 2011).
7) The number of trees that can be treated by the canker mixture is dependent on their age and level of infection.
8) Insect vector insecticide is applied in a water solution that requires 2 ml./tree.
9) The time requirements for black pod removal and black pod burial presented in Table 1 were reduced by 80% to reflect the positive effects of the IDPM activities.

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Theobroma cacao (Cocoa) in the Ramu Markham Valley: A Strength, Weakness, Opportunities and Threats Analysis

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Abstract

In Papua New Guinea, growing cocoa with an overstory of trees is a common agroforestry system in coastal provinces. However, little is known about the growth, yield and profitability of cocoa in the Markham/Ramu valley (RMV). Hence, we undertook interviews with farmers in five villages to find the strengths weaknesses opportunities and threats (i.e. a SWOT analysis) to smallholder cocoa farming in the RMV. A key strength is that cocoa can form approximately half of family cash income. However, prices for cocoa beans fluctuate with supply and are sometimes lower than the cost of production. Government extension assistance is very limited and information concerning insect pests and diseases is not widely available. Cocoa farming is also dominated by men, so promoting it in conjunction with tree growing will only indirectly assist women. Our findings suggest that if cocoa is to be promoted as a means in increasing agroforestry, expert horticultural assistance is required.

1. Introduction

Cocoa agroforestry, i.e. intercropping cocoa with shade trees is used in many countries as a cash crop combined with timber for firewood and house construction. In Papua New Guinea, income from growing cocoa is important to farmers in coastal regions. Income helps villagers meet the cost of education and health services and essential food items that cannot be easily accessed (Nelson et al., 2011). The cash income generated from cocoa production also helps families to meet expenses associated with customary obligations and church activities (Curry et al., 2007b). However, cocoa has not long been established in the RMV and the feasibility and profitability of growing it underneath a popular timber tree, *Eucalyptus pellita* (pellita) is unknown. Little is also known about its susceptibility to insect pests and disease.

Our interest in cocoa was prompted by Australian Centre for International Agricultural Research (ACIAR) project ‘Enabling Community Forestry in Papua New Guinea’. One of the objectives of this project is to research how agroforestry may be best be promoted in the RMV. Unfortunately, growing trees for firewood, house construction is a long-term business. However, cocoa must be grown under shade and this potentially provided an opportunity to promote the usefulness of trees as a provider of shade for cocoa.

A cardinal rule of agricultural extension is never to promote a crop to farmers unless you are aware of any potential problems. Hence, to find out how intensively cocoa is being adopted as a cash crop in the RMV and how farmers view its strengths, weaknesses, opportunities for expansion and any perceived threats, we reviewed the background literature and then interviewed farmers. This provided information from the perspective of the farmers – information which could guide ACIAR extension activities.

2. Methods: Background to cocoa in PNG

Cocoa was introduced to PNG in the 19th Century by German plantation owners. Due to the ideal warm and humid climate, temperature, and frequent rainfall, PNG now produces high quality cocoa which ranks third after oil palm and coffee as a source of export earnings (Bourke and Harwood, 2009). In 2011 the export value of cocoa was PGK320 million (Bank of Papua New Guinea, 2012a; Figure 1.

For the 85% of PNG families who depend on subsistence agriculture (CCI, 2010) the possible appeal of cocoa is that it offers an opportunity to combine a cash crop with timber trees (Bourke & Harwood, 2009). Farmers in the highlands often intercrop coffee as a cash crop in conjunction with *Casuarina oligodon* as a timber tree. In the lowlands, farmers plant pellita, *Gliricidia sepium* (Gliricidia) or bananas with cocoa. Both coffee and cocoa require shade from an overstory tree, so the planting arrangement is one of necessity, not convenience.

How cocoa beans are marketed

Smallholder farmers produce about 87 percent of PNG's cocoa production (Curry et al. 2009b). Cocoa is sold as either 'dry' beans (fermented and dried) or 'wet' bean (beans straight from cocoa pods). Most smallholder cocoa farmers are wet bean sellers even though wet bean prices are lower than dry beans it is costly to build a cocoa dryer and to obtain a cocoa dryer licence (Omuru, 2001).

There are two types of cocoa market in PNG, domestic and export. The domestic market is supplied by most farmers because they do not own a fermentary, i.e. they sell 'wet' beans to registered buyers. A total of 66 wet bean dealers were registered in the 2007 in PNG (CCI, 2009).

In the 'dry' bean market, beans are sold directly to exporters or to registered dry bean buyers who then export them to off-shore processors. Forty one dry bean dealers were registered in 2007 (CCI, 2009). The dry bean buyers either operate independently or act as agents for exporters. There has been also an increasing trend of smallholders fermenting and drying their own cocoa in recent years (CCI, 2010). Almost all large cocoa plantations have fermentaries and sell only dried beans to exporters after quality assessors from the PNG Cocoa Board certify that the products comply with industry standards. Smallholders account for about 80 percent of total bean exports (Papua New Guinea Cocoa and Coconut Institute, 2010).

The Cocoa Board of PNG also issues restrictive and unrestrictive export licenses. Companies with restrictive export licence are permitted to process cocoa (using their own fermentaries) and export it from their farms or plantations only, while those with an unrestrictive export licence are allowed to buy and process cocoa purchased from mostly smallholder farmers for export. There are currently two export companies with restricted licenses and 16 companies (e.g. NGIP AgMark Ltd, Monpi Ltd etc.) with an unrestricted export licence (CCI, 2010).

Over the last ten years (in volume %) the main counties that PNG export cocoa to are USA (32%), Singapore (23%), Indonesia and Malaysia (11% each). The remaining 2% are bought by Australia, New Zealand, the Netherlands, Spain and China (CCI, 2010).

2.1 Undertaking the SWOT analysis

We used semi-structured interviews to assess the strengths, weaknesses, opportunities and threats to current cocoa agroforestry in RMV. The interviews which provided data for our SWOT were conducted in 5 villages; Sankian, Bumpurumpu, Marawasa, Atzunas and Umi in the RMV. These villages are also currently the focus of the ACIAR project. Three smallholder cocoa farmers were interviewed in each village, a total of 15 farmers. We used a SWOT analysis as a means of structuring our questions because farmer's responses can be used to assess specific internal strengths and weaknesses while at the same time looking at external opportunities and threats. In addition to the interview questions, we collected generic demographic data.

3. Results: General demographic data

We found that all the farmers depend on subsistence agriculture, they also undertake paid employment, as opportunities arise. Because women don't have customary land ownership rights, no women owned cocoa farms. However, they participate in activities such as weeding and planting of vegetables and fruits[1]. Summarised demographic characteristics are provided in Table 1.

Farmers manage their land in different ways. Cocoa are planted under Gliricidia, bananas and pellita while vegetables and fruits are planted within the cocoa farm itself. Vegetable and fruits are mainly for own consumption but a small amount of vegetables and fruits are sold to the local market. Cash income is used for household expenses.

Table 1. General characteristics of farmers and families for each village

Characteristic		**Village**				
		Sankian	Bumpurumpu	Marawasa	Atzunas	Umi
Gender	Female	0%	0%	0%	0%	0%
	Male	100 %	100%	100%	100%	100%
Age	30 - 50	70 %	80%	70%	80%	80%
	20 - 29	30%	20%	30%	20%	20%
Percentage of farmers for whom farming is their main livelihood activity		95%	95%	95%	98%	98%
Proportion of cash income derived from cocoa		60%	90%	50%	70%	80%
Size of land for Cocoa farm (ha)	0.1 - 1	100%	100%	100%	100%	100%

3.1 Results of the SWOT analysis: Strengths

Climate and soil

Cocoa grows well in the 'cocoa belt' (between 10 - 20 degrees north and south of the equator). The tropical areas provide the best climates for cocoa where it is warm, humid and wet.
Few cocoa farmers use fertiliser. Sandy loam is common in the RMV and is ideal for cocoa.

[1] In special cases, e.g. where the only child in a family is a women, she may be allowed to own land, which would normally then be inherited by her sons.

Farmers' enthusiasm
Farmers have a basic knowledge of how to grow cocoa. They not only know some of the consequences of a bad agroforestry practices but also the benefits. Farmers have implemented techniques and methods, such as establishment of different shade trees and planting of other vegetable and fruits in the cocoa farms for own consumption or marketing.

Infrastructure and land availability
Farmers have easy access to road leading to towns and local markets. The national Highway connecting the villages to towns/province is in good condition. Hence, farmers are able to carry their products, food and any other inputs by bicycle or public motor vehicles. Smallholder cocoa farmers are traditional land owners therefore they have adequate land to grow cocoa.

3.2 Results of the SWOT analysis: Weaknesses

Lack of basic accounting and management skills and extension assistance
Farmers lack basic accounting and management skills, on how to manage their cocoa blocks and the income they earn from it. There is little extension assistance from the government to assist farmers, either with technology transfer, research or marketing. Farmers also do not have free access to certified high-quality cocoa seed or seedlings. There is no incentive for sustaining the industry in the long run.

Low levels of farm management (pest & diseases)
Inadequate weeding, pruning, shade control and pest and disease control limits cocoa production, but the quantitative qualitative effect of this is unknown. Pest management controls and practices were not adequately understood or followed.

Labour shortages
Most smallholder farmers rely on unpaid family labour for cocoa management. In some families, labour shortages happens as a result from a lack of cooperation amongst household members, often because of uneven distribution of money from cocoa earnings. High mobility and migration of family members due to education, marriage and leisure activities (such as visiting relatives in other provinces) also contributes to a shortage of labour.

Low cocoa prices
Commodity crop producers in PNG experience wide variation in purchase prices because the market prices are negatively correlated with the supply of beans (Curry et al. 2007a Curry et al., 2007b). Farm investment levels consequently declines with falling prices. During times of depressed prices, smallholders are also more likely to search for alternative farm and non-farm income sources to sustain their wellbeing. The cocoa block can then become abandoned and act as a host to pests and diseases. This lack of price security is a major deterrent because sometimes the price is low that farmers are forced to sell their production even though the price will not cover their production costs.

3.3. Opportunities

Cocoa associations or Co-operatives societies
Smallholder cocoa farmers sometimes form associations or co-operative societies, through which to access help from the Government via the Cocoa Board. Most of the cocoa producing provinces have well established network of cocoa cooperative societies, through which the

Cocoa Board regional office implement its extension services. The extension service is also a source of effective networking where the smallholders share knowledge, voice their concerns on factors that affect the farmers, access vital information like prices, and help each other on issues and challenges that confront them and the industry. However, only one of the interviewees has joined a cooperative and is receiving benefits from it.

Markets

There are approximately 8 fermentaries in the RMV that buy wet beans. Although prices vary and sometimes does not cover all the expenses, farmers are guaranteed of being able to sell all their beans.

3.4 Threats

Cocoa Pod Borer (*Conopomorpha cramerella)*

The cocoa pod borer can severely affect cocoa bean production. It is one of the largest threats to the economy and society of cocoa growing provinces, with social and economic impacts potentially worse than other disasters. It still continues to threaten the agricultural families and communities by affecting smallholder cocoa farmers' means of income, making it difficult for them to meet their needs in education and health and to maintain their general quality of life (Curry et al., 2009b). According to Curry et al 2007), most farm management recommendations were developed are for well-managed plantations and since plantations no longer dominate the cocoa industry, those farm management skills are no longer being used (Connell, 1997).

Fire and theft

Fire and theft are a constant threat. People often steal the pods because they want to eat the juice of the beans while following a village track within the cocoa block. Fortunately, most of cocoa blocks are within close range to the farmer's house/village.

Land conflicts and insecure tenure

Land conflicts only happens when people make gardens on other land belonging to other people. Sometimes if a person without traditional land rights develops a piece of land assign to him by traditional land owners which resulted in him/her getting a good income, the traditional land owners can prevent that person to continue using the land.

4. Discussion

The SWOT analysis indicated a requirement for extreme care if timber trees are to be promoted as an overstory for cocoa. Given the uncertainty over cocoa bean prices, it is easy to see why farmers may opt to use gliricidia as a cheap short-term option to provide shade. Similarly, using bananas for shade avoids the long-term requirement for tree growing. Hence, the SWOT indicates that agroforestry cannot rely on cocoa farming to improve the uptake of pellita.

The lack of extension assistance by government agencies is likely to become a key impediment to the cocoa industry as a whole. Cropping systems require a regular supply of new insect pest and fungus resistant varieties to deal with pest as they evolve. This expertise is beyond the capacity of foresters.

Cocoa farming is dominated by men. Hence promoting it in conjunction with tree growing will only indirectly assist women. Because family expenditure is controlled by men, this does not mean that it should not be supported by ACIAR research, but it does little to further the ACIAR objective of empowering women.

Overall, because cocoa can provide as much as half of family cash income, it is still reasonable to promote tree growing through cocoa. However, high price fluctuations for wet beans and a lack of ready extension assistance from the PNG government suggest that ACIAR researchers should adopt a neutral stance in regard to cocoa farming. The main danger is that ACIAR could be held responsible for events which are beyond either their level of expertise or capacity to provide remedies.

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Demonstration Site Design

The design of the site utilizes three blocks; Block A, Block B, and Block C. Blocks A and C have a primary focus of cocoa production, with a total of 232 *Theobroma cacao* (cocoa) trees. Both blocks have a border of *Manihot* sp. (cassava) plants and a border of *Musa* sp. (banana)/shade trees to act a buffer against fires. The shade tree species in Block A are *Eucalyptus pellita* (Eucalyptus), which were selected for their use as a fuelwood and for home construction materials. The shade tree species in Block B is split between *Gliricidia sepium* (Gliricidia) and *Intsia bijuga* (Kwila). *Gliricidia sepium* was selected for its ease of establishment and nitrogen fixing properties. *Intsia bijuga* is a high-value timber species, but it does not grow well in an open-sun/plantation environment. It was selected to demonstrate that it should not be used as a shade-crop tree, despite the interest in its use by local landowners. The trees in Blocks A and C are intercropped with *Cucurbita* sp. (pumpkin), *Phaseolus* sp. (beans), and *Sechium edule* (choko) to aid in weed control, nitrogen fixation, and the provision of additional crop income.

Block B has a primary focus of agricultural production. The main agricultural crop is *Ipomoea batatas* (sweet potato), which is grown in a sub-plot with *Zea mays* (corn). The sweet potato and corn sub-plot is grown at staggered intervals in each of the four corner sub-plots in Block B. The remaining agricultural crops are; *Citrullus lanatus* (watermelon), *Solanum* sp. (tomato), *Capsicum* sp. (chili pepper), *Allium fistulosum* (spring onion), and *Abelmoschus manihot* (aibika). Each of these remaining crops has an adjacent sub-plot that lies fallow every other year and is planted with *Phaseolus* sp. (beans). Block B also incorporates two tree species; *Canarium indicum* (Galip) for nut production, and *Gnetum gnemon* (Tulip) to produce leafy greens.

Background Information

The Umi agroforestry demonstration site was established as an agri-silvicultural system. A combination of trees and cash crops/vegetables were planted in a one-half hectare plot. The aim of this demonstration site is the establishment of an agroforestry system that addresses issues commonly faced by local farmers such as fire control, soil nutrient depletion, weed control, low cocoa yield, availability of different food crops year-round, the availability of fuel wood (firewood), and the provision of house construction materials. The site is located in the Ramu Valley, at coordinates 6°10’54.57”S and 146°10’53.01”E. The species selected for the site were based on a community preference survey, conducted in the Marawasa and Atunas communities.

Early growth - February 2019

Banana and Eucalyptus - February 2020

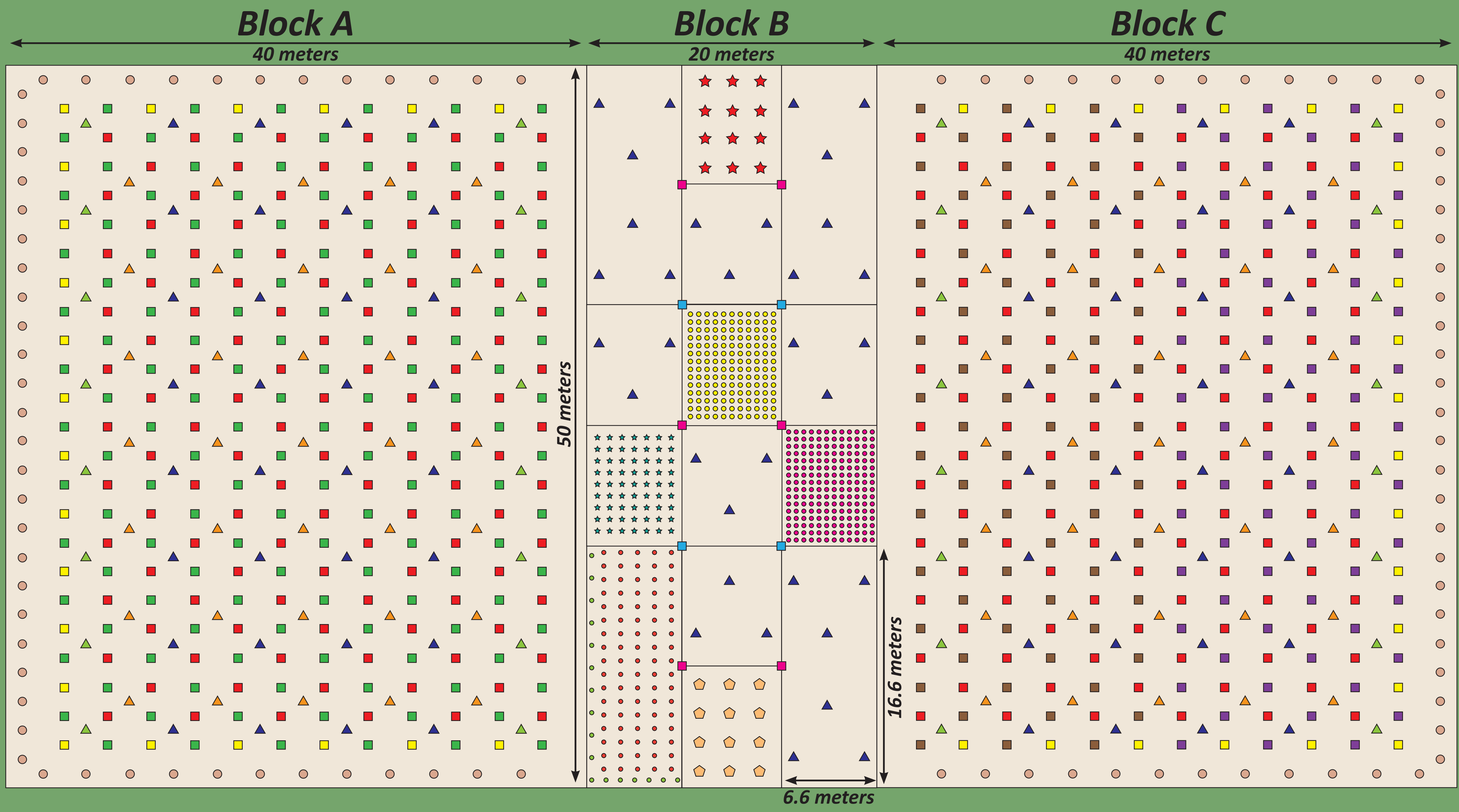
Australian Government
Australian Centre for International Agricultural Research

Umi Agroforestry Demonstration Site

April, 2020

ACIAR Project FST-2016-153

ACIAR



Tree Crops

Theobroma cacao (Cocoa)	232
Gnetum gnemon (Tulip)	6
Musa sp. (Banana)	44
Eucalyptus pellita (Eucalyptus)	137
Canarium indicum (Galip)	4
Gliricidia sepium (Gliricidia)	68
Intsia bijuga (Kwila)	69

Vegetable Crops

Manihot sp. (Cassava)	96
Ipomoea batatas (Sweet potato)	85
Zea mays (Corn)	17
Allium fistulosum (Spring onion)	192
Solanum sp. (Tomato)	154
Cucurbita sp. (Pumpkin)	70
Sechium edule (Choko)	16
Phaseolus sp. (Bean)	97
Abelmoschus manihot (Aibika)	7
Capsicum sp. (Chili pepper)	63
Citrullus lanatus (Watermelon)	12

ACIAR Project FST/2016/153 Enabling Community Forestry in Papua New Guinea

Commencement Report

Activity 1.3

Title: AS 307 R570 Variable Spacing Trial

Compiled by: Zephaniah Waviki

18th March, 2020

1.0 Introduction

It is critical to identify suitable tree species and planting systems in promoting large-scale community-based forestry programs in Papua New Guinea. However, there is a dearth of information regarding the growth of many tree species that are potential for reforestation programs and smallholder tree farming projects in the country. While there are publications outlining likely site requirements, growth estimates and suggested silvicultural systems for both exotic and indigenous species for tropical countries, these are seldom based on evidence of actual growth from rigorous field trials. For most tree species, there is a lack of data on species performance on different sites and under a range of site conditions. There is also little information on optimal planting density and planting configurations that promote early site capture and maximum growth of trees.

The prescribed activity is to identify the key tree species for early site capture and what key species should be planted together to promote the development of good stem form, improved performance, greater competition or no interactions.

A variable Spacing trial was established in the Upper Ramu Valley by ACIAR Project Foresters in Ramu Agri industries (RAIL) with remote guidance from Research Fellow Nestor Gregorio from University of Sunshine Coast, Australia.

2.0 Research Questions

This study aims to answer the following research questions:

1. What tree species demonstrate high potential suitability for community forestry in the Ramu Markham Valley and other areas in Papua New Guinea?
2. What is the optimal spacing for the early site capture of key forestry species?
3. At what spacing the key species should be planted to promote the development of good stem form for sawlog production?
4. What is the optimal period to apply thinning and pruning treatments to facilitate the production of trees with good stem form for maximum timber recovery?

3.0 Significance of the Experimental results

The results will be captured to answer the fundamental research questions that can be used to promote community forestry in the dominated grassland of the Ramu Markham valley.

4.0 Research Methods and Materials

The selected species, planting site, experimental design and subsequent activities detail are as follows.

4.1 Trial Site location

The trial site is located in Usino Bundi District in Madang Province. The site is adjacent to A South 307, name of the nearest Sugar cane field. It is situated on the RAIL's operational leases declared for Forest rehabilitation and is about 8 kilometres from RAIL's Industrial area and offices. The specific coordinates of the area is UTM 55 03699337 S 9342044 E. An area disconnected from a strip of an existing strip forest. The vegetation cover was dominated by *Sacchrum spontaneum (wild sugar cane)* with thin scattering juvenile *Samanea saman* (rain tree). The land is generally flat and homogenous regarding aspect and surface configuration consisting of vertisols soil characteristics. The general annual average rainfall of the upper Ramu is 1950 mm per year [1]. Figure 1 below shows the site location for the trial establishment.

4.2 Species

Four species of interest were identified and planted. The species selection was based on the locality of the species in relation their ecological features, dominancy and socio-economic aspects. The species were categorized as PNG tropical hardwood species. Table 1 presents the 4 species and their general end uses which compliments the local species of choice.

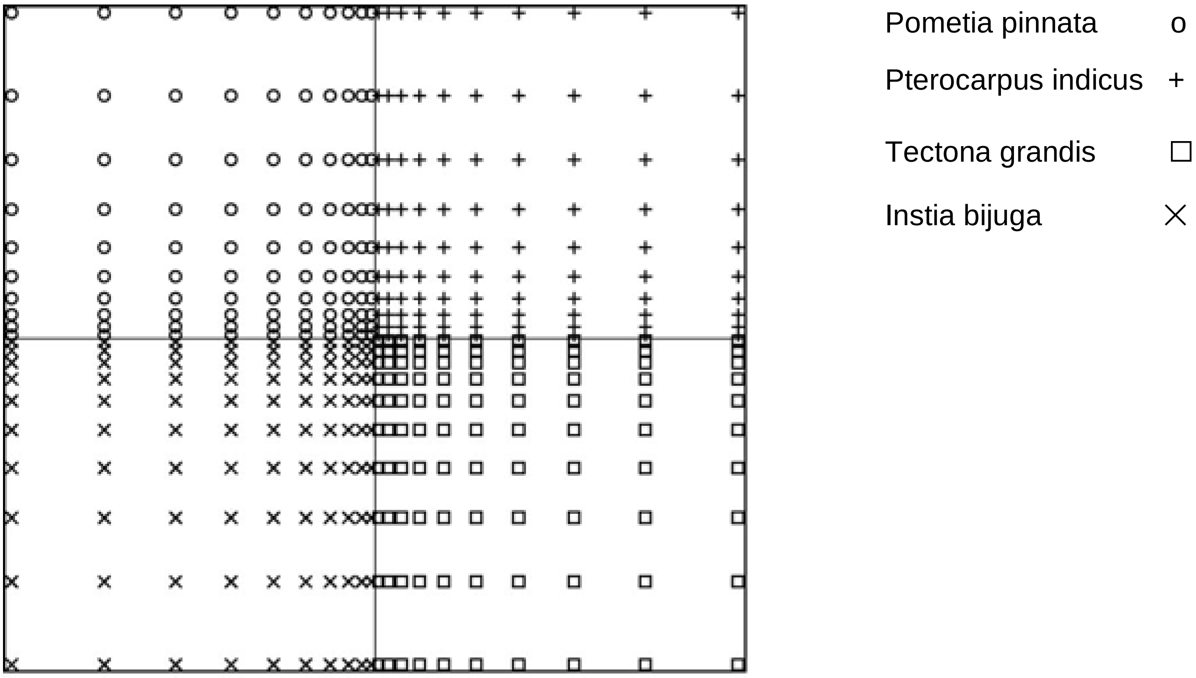
Species No	Species Name	Common Name	Choice for selection
1	*Pometia pinnata*	Taun	Considered as a "B" graded red wood species, seeds are edible; good source of fuel wood; provides shade and other environmental services.
2	*Pterocarpus indicus*	Rose wood	Considered as a premium timber by the Industry. Now categorized vulnerable due to over exploitation. Extensive root system that can be used to protect soil erosion along seasonal streams and permanent water courses.
3	*Tectona grandis*	Teak	Quality timber for furniture and post, fire resistant and smothers weeds.
4	*Instia bijuga*	Kwila	Premium tropical timber for construction and furniture. Considered vulnerable due to its demand by the industry. Exclusive environmental services.

4.3 Field trial Design

The field trial design is adopted from a similar trial that was established in the FLR Project in the Philippines (Gregorio, 2020).

A variable spacing trial will be established to determine the optimum spacing of trees that will Promote early site capture and production of high-quality sawlogs. The experimental design is set out in Figure 1. The variable spacing trial design is informed by the suggestions of Vanclay (2006). This innovative design allows information to be collected on four most preferred timber species within a compact 60 m x 60 m block layout. The block is divided into four plots, and each plot will be planted with a single species. The symbols correspond to the four species that will be planted The seedlings will be planted with the following distances (in meters) from the centre of the block: 1 (0.3), 2 (1.10), 3 (2.20), 4 (3.60), 5 (5.60), 6 (8.20), 7 (11.60), 8 (16.10), 9 (21.90) and 10 (29.40).

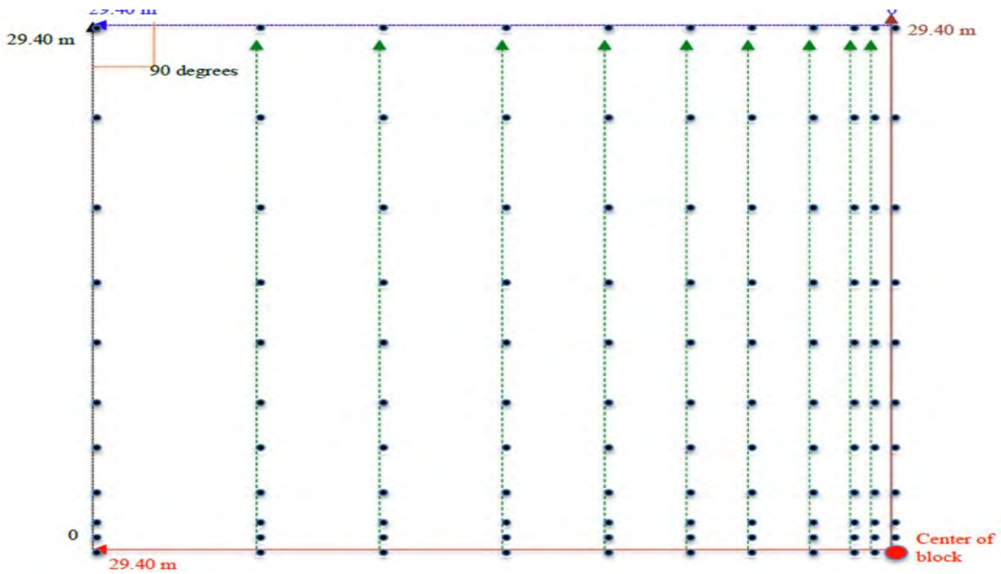
Figure 2 The planting layout of the trees in the variable spacing trial (adopted from Vanclay 2006)



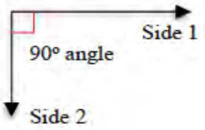
4.4. Establishment of Experimental block

The planting site with a dimension of 65 m x 65 was established (Figure 3). Figures 4 -6 show the plot trial designs and planting spaces, extracted from Nestor Gregorio's notes.

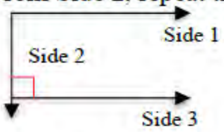
Figure 4. Trial plot set-up



2. Using the compass (or 3-4-5 method), measure a 90-degree angle left or right from Side 1, depending on where the experiment block will be oriented. Establish another 60 m line following the 90-degree angle from Side 1. Consider this as Side 2.



3. From Side 2, repeat the procedure to establish Side 3.



4. From Side 3, repeat the same procedure to establish Side 4. The four lines will comprise the four sides of the experiment block.

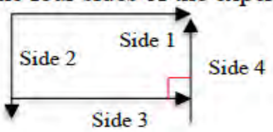
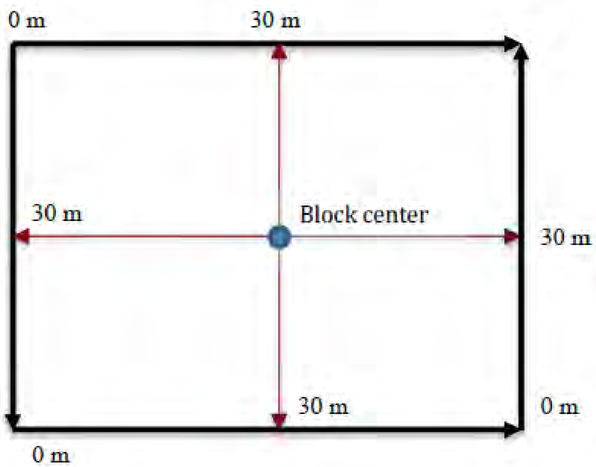


Figure 5. Schematic plot layout



4.5. Site Preparation

Prior to plot set up the initial site was covered with overgrown *sacchrum spontaneum* (wild cane grass). The area was slashed using the tractor with mounted slasher to have the trial plot pegged out. The slashed biomass was left to decompose as an additional humus to the soil.

4.6. Plot Pegging Layout

Figure 6 was established using a calibrated 31 meter rope, pegs, a 100 meter survey tape and a flagging tapes. Four corners of the plot were marked with long sticks including the center of the plot. See figure 5 for details. The pegs were sticks cut and calibrated from the nearby *Leucaenna sp* and *Glirichidia sepium* woodlots along the Ramu tributary.

Plot pegging were done after steps discuss in Figure 4 were carried out.

The calibrated 31 meter rope was marked with flagging tapes tied on the rope. The calibrated 31 meter rope was held in length wise by two personnel at either side of the subplot with 3 people pegging the planting spots as indicated by the flagging tapes on the ropes. This was done until 100 planting spots in each 4 subplots were completed totaling 420 planting spots.

4.7. Planting Site Preparation

Planting eventuated the day right after plot pegging. 20 cm x 20 cm x 20 cm holes were dug to suit the 158mm x 250mm x 40mm poly bag containing the seedling. The holes were ideally dug to cater for the root system development. 420 holes were dug in total.

4.8. Planting

The seedlings were transported in loads of 50 in galvanized planting tray for keeping the seedlings from shock and polybags movements. 8 tray loads of seedlings were transported and placed in the nearby riparian buffer for adequate shade and shock recovery. The seedlings were transported a day early for planting convenience.

Planting commenced on March 03, 2020, coincided with the rainy season. Planting completed on the same day because of proper coordination and supervision. 8 team members conducted the plantings in 3 hours.

A wheelbarrow was used to haul the seedlings to the subplots. Each seedling was placed to the holes dug until complete. Seedlings were careful removed from the polybags by tearing along the perforated lines on the side of poly and bag placed gently into the hole. Soil was filled to the root collar and covered with minimal hand pressure to ensure aeration and nutrients movements for the newly established seedlings.

Figure 2 shows the planting establishment configuration.

4.9. Maintenance of the Trial Plot

Due to the recurring behavior of the *S. spontaneous* and as the dominion species on the trial site, manual and mechanical maintenance are of paramount to have it under control. Plot maintenance of ring weeding was done at the base of each seedling at a meter radius. The plot maintenance will be scheduled with the other plots maintenance as per the weed recurrence and intensity.

Mechanical slashing only applies to the boundaries and the widen areas inside the trial plot as per the trial design.

Use of chemical will be considered upon assessment of growth intensity. An SOP has not yet been drafted to capture the safety component as per RAIL's OHS policy.

Regular monitoring is ongoing to deter seedling damage from local, fire threats, sugar chemical spraying in the adjacent sugar field.

4.10. Fire Management

A 7 meter fire management was initiated with a gross buffer established outside the plot with the replica of each species at a spacing of 3 m x 3 m interval. The reason for the spacing is for allowable passage for the tractor to do its routine mechanical slashing.

4.11. Trial Measurements

The parameters of measurement to be captured are seedling diameter, height, seedling mortality and general health of the seedlings. Diameter was measured from the base with a digital calipher whilst the height is measured with a 100 cm ruler stick for consistency. Initial measurements were initiated after 2 weeks due to continuous rain and slippery muddy roads.

4.12. Data management and Analysis

4.12.1. Data Collection form

A generic Microsoft excel field sheet xls from Trial 001 16 Species Mixed Trial has been customized to capture the quantitative data (See Form in Appendix). A measurement schedule will be effected every 3 months after the initial plot measurement.

4.12.2. Data Collection Procedure

It was customized as per the trial design and plot configuration to maintain consistency when data assistants are doing the field measurements. Appendices 1 explains the procedure for data collection.

The first 4 seedlings at the center of the plot are each measured as per Appendices 2.

4.12.3. Data Compilation and Analysis

Collected data will tabulated into the customized Microsoft excel. The process continue as per measurement duration and project life.

5. Photo assay of VST

a. Site Preparation

Figure 7 (a) Block marking using the 3-4-5 methodology (b) Pegs prepared for planting spots marking

a. Seedling Preparation for Transportation

b.

Figure 8 (a, b, c) Seedling preparation in RAIL Nursery for transportation to planting site

c. Planting

(a) Digging of planting holes **(b) Planting hole approx. 30cm depth** **(c) Planting**

References

- Remote sensing applications for peanuts in Australia and Papua New Guinea - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Average-rainfall-observed-in-the-Markham-Valley_tbl23_303331422 [accessed 28 Feb, 2020]
- Vanclay JK (2006) Experiment designs to evaluate inter- and intra-specific interactions in mixed plantings of forest trees. Forest Ecology and Management 233(2-3):366–374

Appendix

1. Measurement Form Template

			Measurement No. 02		BY:VITUS JOHN	
			Date	04-Mar-20		
BLOCK NO	Plant No	Column	Species	Heigh	Base Diameter (mm)	Comments
1	52		*Ton*			
	53		*Ton*			
	54	5	*Ton*			
	55	6	*Ton*			
	56		*Ton*			
	57		*Ton*			
	58		*Ton*			
	59		*Ton*			
	60		*Ton*			
	61		*Ton*			
	62		*Ton*			
	63		*Ton*			
	64		*Ton*			

COMMENCEMENT REPORT

Expt Reference: FST/2016/153 – Field Trial # 02, Goroka, PNG

Field Files: Phase 1: Expt No 02. (Establishment date: 16/04/2021
Phase 2: Expt No (date to be established.)

Title: Variable Spacing Trial

Subtitle for phase 1:
Subtitle for phase 2:

Preamble:

The selection of tree species and design of planting systems in promoting large-scale community-based forestry programs in Papua New Guinea is crucial in order to demonstrate to interested tree farmers and communities. However, there is a dearth of information regarding the growth of many tree species that are potential for reforestation programs and smallholder tree farming projects in the country. While there are publications outlining likely site requirements, growth estimates and suggested silvicultural systems for both exotic and indigenous species for tropical countries, these are seldom based on evidence of actual growth from rigorous field trials. For most tree species, there is a lack of data on species performance on different sites and under a range of site conditions. There is very limited information on mixed-species plantings, especially about complementarity or antagonistic relationships when planted together. There is also little information on optimal planting density and planting configurations that promote early site capture and maximum growth of trees of lowland species in the Highlands of Papua New Guinea.

Research questions:

This study aims to answer the following research questions:

1. What tree species demonstrate high potential suitability for community forestry in Goroka and other areas in Papua New Guinea?
2. What is the optimal spacing for the early site capture of key forestry species?
3. At what spacing the key species should be planted to promote the development of good stem form for sawlog production?
4. What is the optimal period to apply thinning and pruning treatments to facilitate the production of trees with good stem form for maximum timber recovery?
5. Do species combinations provide improved performance, greater competition or no interactions i.e. what species should be planted together and what species combinations should be avoided?

Experiment design

Trial # 02 – Variable Spacing trial (Kintinu)

Trial # 02 – Variable Spacing trial was established within Kintinu area (Refer to Map attachment) to identify which species combinations provide improved performance, greater competition or no interactions i.e. what species should be planted together and what species combinations should be avoided. The same species used in the variable spacing trial were used in the mixed planting trial. The experiment layout was done with assistance of FRI Officer *(Haydrian Morte)* for the testing species interactions of four species at a range of different 4 replicates. Seedlings were planted at the spacing of variable spacing design of USC. This 4 species planting trial will provide valuable information about the interactions of the four species when grown in varying mixture ratios.

Future management of phase 1:

During establishment phase initial field measurements was carried out at out planting and to continue every three months thereafter for the first year. Measurements will then be done at six months until year five and then once a year afterward. Seedling mortality, height, base diameter, photosynthetic rate and general health were recorded. Other parameters including light intensity, and soil and air temperature and humidity will also be measured in same trial plots. Diameter at breast height will be recorded as soon as the trees reach 3 meters. Seedling height was measured using a 30cm rule while seedling base diameter was determined using a digital caliper.

Ring weeding is to be undertaken every quarter until year three. Regular tending to reduce the risk of grassland fire is carried out every six months or whenever necessary *(suggest every 3 months due to fast growth of weeds in the plot)*

Method and Materials:

Establishing the field trials involves a series of activities including a reconnaissance survey, establishing formal arrangements and legal agreements with the owners of the land where the trials will be established, meetings with clan where necessary was done to inform them about the trial, field planting, placing of signboards to advertise the trials, and possibly employing a local resident to oversee the experiments. The trial is established on customary land with land agreement fully documented using FRI land agreement form.

The experimental design is Variable Spacing Trial adopted from USC. The boundary of plot (60m x 60m) size was surveyed using Suunto Compass and permanent corner pegs inserted with colored ribbons for ease in distinguishing the 4 corners. Experimental layouts were established using surveyor's tape and calibrated ropes. The 3-4-5 method of establishing plot corners was applied and straightness of planting lines was determined using a compass. Pegs were used to mark the planting spots and marked with colored ribbons corresponding to the four species that were used in the trials.

Planting holes were established on each planting point and seedlings of corresponding species were planted by inserting each seedling in the planting hole and root systems covered with soil up to the root collar level. Seedlings were watered after planting. Watering continued every day for a period of two months because of nearing end of dry season during field trial establishment. Fence was established around the experimental plots to protect the seedlings from potential damage by grazing ruminants and pigs.

Materials & Equipment's Used
- 1 x Suunto Compass
- 1 x 50m tape
- Colored ribbons

- Fencing Materials
- Pig wire rolls, Barbed Wire rolls, Wooden Posts & hand tools

Location: Kintinu village, Bena District, Goroka. EHP
(*See location Map of Trial attached).*

Grid reference: UTM

Latitude & Longitude
South 06^{0} $14^{!}$ 30. $3^{!!}$
Easting 145^{0} $29^{!}$ $32.9^{!!}$

Soil Type:

O & A Layer (Organic/Top soil) Clay Loam
B Layer (Subsoil) – Clayish
Overall description: Clay Loam - Black

Aspect/Slope:
South East @ 25%

South East @ 15% slope

Altitude

1581 m (als)

Rainfall:
Mean annual rainfall
Average rainfall @ 2,400 mm/year
Average monthly @ 205mm/year

Site Preparation:

Clear brushing of thick imperata grassland & burn

- *FRI Officer Haydrian Morte with assistance of local labour marking layout of trial # 02 - Kintinu*

Planting:

Dig holes within center of pegs @ a depth of 20 cm and plant

Weed Control:

Hand weeding

Chemical application

Fertilizer:

Fertilizer compound (13, 12, 20) to be applied once 3 months after planting and 6 months thereafter.

Amount, concentration and application of 150grams per tree (3months after planting)

Fencing: Pig Wire, Barbed Wire, & wooden Pegs

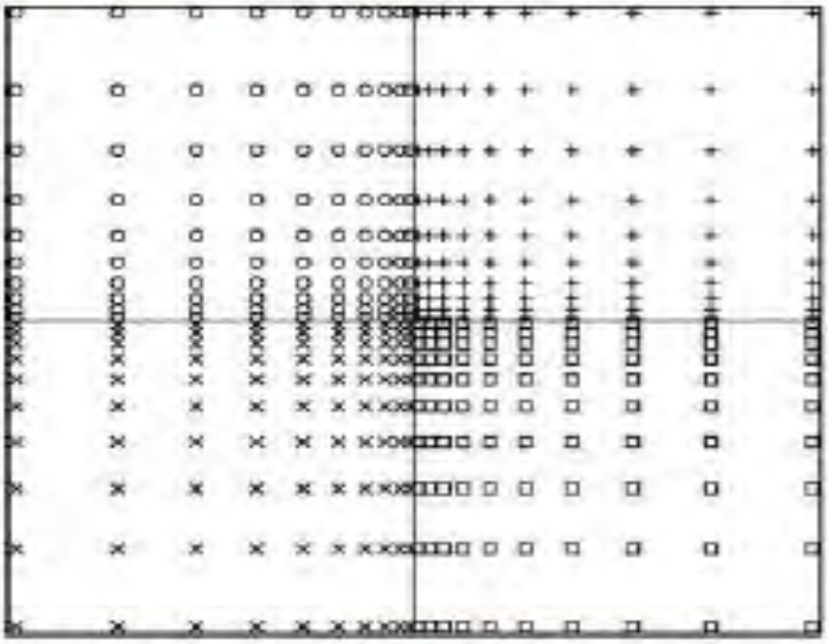
- *Photo view of Fencing done using pig wire & Wooden posts by local labour in picture*

Species Details

Trial # 02 – Kintinu - Four (4) species of economic and social importance were selected to be tested for this site. The following list species below,

Tectona grandis (Teak) *Kuriva Provenance*
Eucalyptus pelita – (*Markham Provenance)*
Homalium foetidum (Malas) *Morobe Provenance*
Toona Sureni (Red Cedar) *Morobe Provence*

Appendix1: Design and Plot Layout



Design

Plot Layout

8

Prepared by: Warea Andasua

Date: 27/05/2021

Introduction to R Software for Variable Spacing Species Trial Analyses
Online Workshop Report

Report prepared for activity 1.3 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder
October 2022

1 Introduction:

This workshop was designed to introduce project partners to some of the analysis techniques used for variable spacing tree species trials. This analysis was performed with R software. R is an open-source software programme that is designed for data analysis. Numerous additional sub-programmes for R have been developed, called packages. The package presented in this workshop was 'Siplab.' The Siplab package allows the user to produce 'Hegyi Competition Indices' with a 'Pairwise' function. The Hegyi competition indices are used to assess how much competition individual trees are experiencing relative to their spacing distances from other trees. In addition, workshop participants were introduced to analysis and chart making techniques using R and Microsoft Excel.

2 Workshop dates and subjects:

Tuesday 4th October (10:00 AM - 12:00 PM):

- Introduction to R software features.
- Introduction and practice of code scripts with the 'Iris' dataset (example dataset provided with R).
- Introduction to the Siplab package.

Wednesday 5th October (10:00 AM - 12:00 PM):

- Review of the Siplab package.
- Introduction to data cleaning process.
- Overview of Siplab code scripts to conduct analysis on species trial dataset.
- Introduction to analysis techniques from Siplab outputs.

FST 2016/153 | ENABLING COMMUNITY FORESTRY IN PAPUA NEW GUINEA

ESTABLISHING FIELD TRIALS

A SIMPLE GUIDE TO

ESTABLISHING FIELD TRIALS

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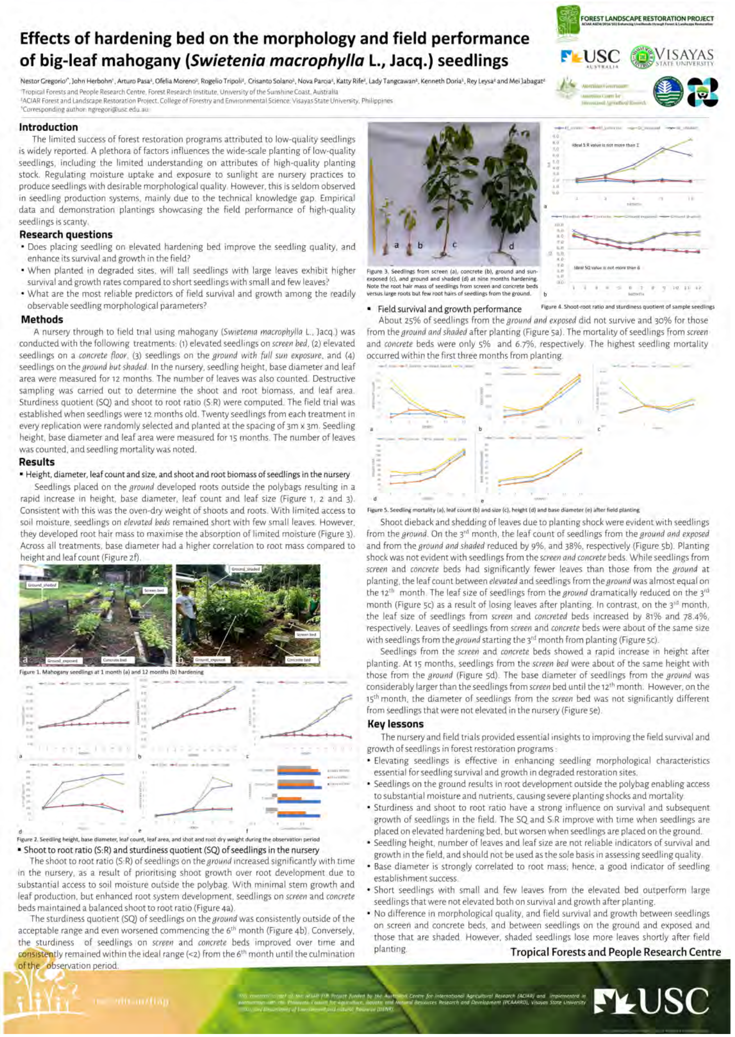

Effects of hardening bed on the morphology and field performance of big-leaf mahogany (*Swietenia macrophylla* L., Jacq.) seedlings

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Introduction

The limited success of forest restoration programs attributed to low-quality seedlings is widely reported. A plethora of factors influences the wide-scale planting of low-quality seedlings, including the limited understanding on attributes of high-quality planting stock. Regulating moisture uptake and exposure to sunlight are nursery practices to produce seedlings with desirable morphological quality. However, this is seldom observed in seedling production systems, mainly due to the technical knowledge gap. Empirical data and demonstration plantings showcasing the field performance of high-quality seedlings is scanty.

Research questions

- Does placing seedling on elevated hardening bed improve the seedling quality, and enhance its survival and growth in the field?
- When planted in degraded sites, will tall seedlings with large leaves exhibit higher survival and growth rates compared to short seedlings with small and few leaves?
- What are the most reliable predictors of field survival and growth among the readily observable seedling morphological parameters?

Methods

A nursery through to field trial using mahogany (*Swietenia macrophylla* L., Jacq.) was conducted with the following treatments: (1) elevated seedlings on *screen bed*, (2) elevated seedlings on a *concrete floor*, (3) seedlings on the *ground with full sun exposure*, and (4) seedlings on the *ground but shaded*. In the nursery, seedling height, base diameter and leaf area were measured for 12 months. The number of leaves was also counted. Destructive sampling was carried out to determine the shoot and root biomass, and leaf area. Sturdiness quotient (SQ) and shoot to root ratio (S:R) were computed. The field trial was established when seedlings were 12 months old. Twenty seedlings from each treatment in every replication were randomly selected and planted at the spacing of 3m x 3m. Seedling height, base diameter and leaf area were measured for 15 months. The number of leaves was counted, and seedling mortality was noted.

Results

- **Height, diameter, leaf count and size, and shoot and root biomass of seedlings in the nursery**

Seedlings placed on the *ground* developed roots outside the polybags resulting in a rapid increase in height, base diameter, leaf count and leaf size (Figure 1, 2 and 3). Consistent with this was the oven-dry weight of shoots and roots. With limited access to soil moisture, seedlings on *elevated beds* remained short with few small leaves. However, they developed root hair mass to maximise the absorption of limited moisture (Figure 3). Across all treatments, base diameter had a higher correlation to root mass compared to height and leaf count (Figure 2f).

Figure 1. Mahogany seedlings at 1 month (a) and 12 months (b) hardening

Figure 2. Seedling height, base diameter, leaf count, leaf area, and shot and root dry weight during the observation period

- **Shoot to root ratio (S:R) and sturdiness quotient (SQ) of seedlings in the nursery**

The shoot to root ratio (S:R) of seedlings on the *ground* increased significantly with time in the nursery, as a result of prioritising shoot growth over root development due to substantial access to soil moisture outside the polybag. With minimal stem growth and leaf production, but enhanced root system development, seedlings on *screen* and *concrete* beds maintained a balanced shoot to root ratio (Figure 4a).

The sturdiness quotient (SQ) of seedlings on the *ground* was consistently outside of the acceptable range and even worsened commencing the 6[th] month (Figure 4b). Conversely, the sturdiness of seedlings on *screen* and *concrete* beds improved over time and consistently remained within the ideal range (<2) from the 6[th] month until the culmination of the observation period.

Figure 3. Seedlings from screen (a), concrete (b), ground and sun-exposed (c), and ground and shaded (d) at nine months hardening. Note the root hair mass of seedlings from screen and concrete beds versus large roots but few root hairs of seedlings from the ground.

Figure 4. Shoot-root ratio and sturdiness quotient of sample seedlings

- **Field survival and growth performance**

About 25% of seedlings from the *ground and exposed* did not survive and 30% for those from the *ground and shaded* after planting (Figure 5a). The mortality of seedlings from *screen* and *concrete* beds were only 5% and 6.7%, respectively. The highest seedling mortality occurred within the first three months from planting.

Figure 5. Seedling mortality (a), leaf count (b) and size (c), height (d) and base diameter (e) after field planting

Shoot dieback and shedding of leaves due to planting shock were evident with seedlings from the *ground*. On the 3[rd] month, the leaf count of seedlings from the *ground and exposed* and from the *ground and shaded* reduced by 9%, and 38%, respectively (Figure 5b). Planting shock was not evident with seedlings from the *screen and concrete* beds. While seedlings from *screen* and *concrete* beds had significantly fewer leaves than those from the *ground* at planting, the leaf count between *elevated* and seedlings from the *ground* was almost equal on the 12[th] month. The leaf size of seedlings from the *ground* dramatically reduced on the 3[rd] month (Figure 5c) as a result of losing leaves after planting. In contrast, on the 3[rd] month, the leaf size of seedlings from *screen* and *concreted* beds increased by 81% and 78.4%, respectively. Leaves of seedlings from *screen* and *concrete* beds were about of the same size with seedlings from the *ground* starting the 3[rd] month from planting (Figure 5c).

Seedlings from the *screen* and *concrete* beds showed a rapid increase in height after planting. At 15 months, seedlings from the *screen bed* were about of the same height with those from the *ground* (Figure 5d). The base diameter of seedlings from the *ground* was considerably larger than the seedlings from *screen* bed until the 12[th] month. However, on the 15[th] month, the diameter of seedlings from the *screen* bed was not significantly different from seedlings that were not elevated in the nursery (Figure 5e).

Key lessons

The nursery and field trials provided essential insights to improving the field survival and growth of seedlings in forest restoration programs :

- Elevating seedlings is effective in enhancing seedling morphological characteristics essential for seedling survival and growth in degraded restoration sites.
- Seedlings on the ground results in root development outside the polybag enabling access to substantial moisture and nutrients, causing severe planting shocks and mortality.
- Sturdiness and shoot to root ratio have a strong influence on survival and subsequent growth of seedlings in the field. The SQ and S:R improve with time when seedlings are placed on elevated hardening bed, but worsen when seedlings are placed on the ground.
- Seedling height, number of leaves and leaf size are not reliable indicators of survival and growth in the field, and should not be used as the sole basis in assessing seedling quality.
- Base diameter is strongly correlated to root mass; hence, a good indicator of seedling establishment success.
- Short seedlings with small and few leaves from the elevated bed outperform large seedlings that were not elevated both on survival and growth after planting.
- No difference in morphological quality, and field survival and growth between seedlings on screen and concrete beds, and between seedlings on the ground and exposed and those that are shaded. However, shaded seedlings lose more leaves shortly after field planting.

Tropical Forests and People Research Centre

The results of the field trial will not be useful if these are not written and conveyed to stakeholders. Research reports, briefing notes, working papers and scientific publications are some of the forms of sharing findings of the field trial. The report should include the rationale of the field trial; the methods used in setting up the trial, and collecting and analysing data; the key results and implications. It is always helpful to go back to the field trial design as this will serve as an outline in crafting the report.

A SIMPLE GUIDE TO

ESTABLISHING FIELD TRIALS

It is critical to identify suitable tree species and planting systems in promoting large-scale community-based forestry programs in the tropics including the Papua New Guinea. However, there is a dearth of information regarding the growth of many tree species that are potential for reforestation programs and smallholder tree farming projects in the country. While there are publications outlining likely site requirements, growth estimates and suggested silvicultural systems for both exotic and indigenous species for tropical countries, these are seldom based on evidence of actual growth from rigorous field trials. For most tree species, there is a lack of data on species performance on different sites and under a range of site conditions. There is very limited information on mixed-species plantings, especially about complementarity or antagonistic relationships when planted together. There is also little information on optimal planting density and planting configurations that promote early site capture and maximum growth of trees. These gaps of knowledge necessitate the establishment of field trials.

The research project FST/2016/153 of the Tropical Forests and People Research Centre at University of the Sunshine Coast with auspice from the Australian Centre for International Agricultural Research (ACIAR) provides the opportunity to forestry professionals in PNG to establish field trials in support to the objective of the project to _______. This manual was developed to provide forestry technicians and researchers the basics of establishing a field trial. It is not a comprehensive guide to establishing field trials but it presents the methods of designing, establishing and monitoring field trials that are simple to follow by less experienced researchers.

PLANNING THE FIELD TRIALS

A research plan is essential prior to the establishment of field trial. It provides justification of the research and serves as guide on how the field trial will be established. The research plan will also serve as outline of the research report. The plan should include the following information:

Research Title

Identifies the nature and scope of the research

Author/s

Indicates the names of those with significant involvement in the field trial including conceptualising the research, designing the trial, establishing the trial, collecting and analysing data, and making reports and scientific articles. In many cases, authorship depends on the discretion of the principal researcher. Authorship guidelines exist in some institutions.

Abstract

An abridged version of the field trial which provides statements of the problem and issues to be addressed, the hypothesis to be tested and summary of the research method.

Introduction

Highlights the issues and problems to be addressed by the field trial in relation with real world situation, justification of the research, and relevant research findings and information from various sources.

Statement of objectives

Describes clearly what the research needs to accomplish

Treatment Specifications

Discusses the research variables and how they are identified, and how they will be controlled and measured. The treatments should clearly relate with the objectives. As much as possible, treatments should have contrasting relationships e.g. with mycorrhiza and without mycorrhiza; with fertilizer and without fertilizer. A control may be included for the purpose of comparison. The control could be a treatment that is established to show good results or no treatment at all. The latter is usually used for experiments including applications of fertilizer, mycorrhiza, herbicides, and growth hormones.

Research methods

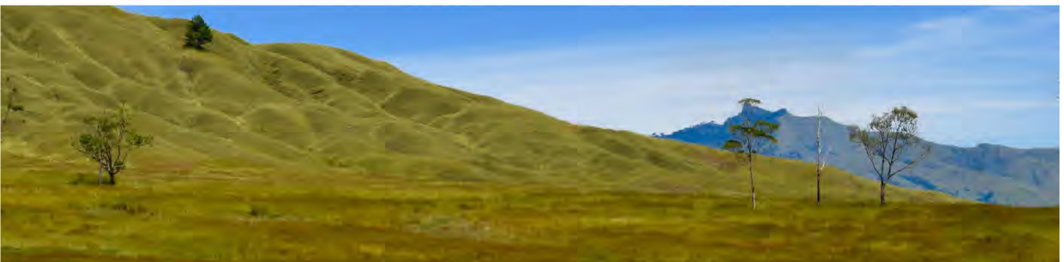
Presents the details on how the field trial is established including the field trial layout reflecting the number of treatments, replications, plot size, block size, plot orientation, and planting distance; the site preparation activities; and trial establishment and monitoring procedures. The methods section also shows the treatment application if necessary, the data to be collected and measurement procedure, and data organisation and analysis to be undertaken.

Budgetary requirement

A detailed presentation of proposed budgetary requirements showing the proposed expenses per activity and the total funds needed in carrying out the field trial.

Reference

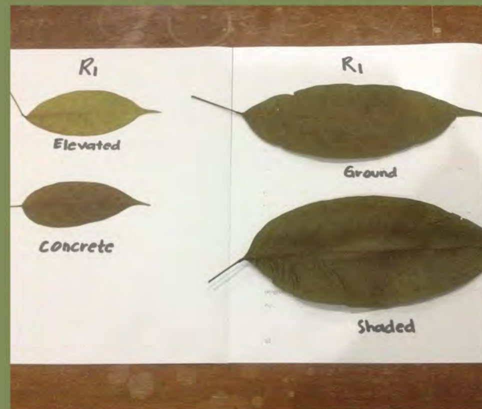
Published articles relevant to the field trial that will help justify the research, reinforce the methods and aid in explaining the results.



DATA ORGANISATION AND ANALYSIS

Data cleaning and organising should be undertaken immediately after data collection is completed. Data cleaning will determine some errors in the measurement and recording process, which can be rectified easily if detected shortly after data collection. Data organising must be designed to allow the use of specific analysis that will be undertaken.

There are many tools that can be used of data analysis. The choice will depend on the type of experiment and proposed analysis that will be conducted, and the cost of obtaining the programs. There are free softwares that are robust enough for performing basic data analysis. The researcher should consider these free programs prior to deciding the purchase of product licences, which are usually expensive. The Microsoft Office comes with Access and Excel. These programs are useful tools for organising and analysing research data.



FIELD TRIALS DATA COLLECTION

Assessing seedling health is largely qualitative and based on judgement of the person collecting the data. It is better that only one person will assess seedling health for consistent result. Alternatively, more than one individuals can undertake the assessment and mean observations will be computed. The following scale can be used for assessing seedling health:

1	Excellent	No signs or symptoms pests and disease
2	Fair	Minor occurrence of pests and diseases
3	Poor	Signs and symptoms of diseases are evident
4	Very poor	Seedling is showing advance stage of signs and symptoms but not dying
5	Dying	Seedling is likely to die because of pests and diseases

Assessing Stem Form

A scale of 1 to 5 can be used in grading stem form with 1 as the best and 5 as the worst. The following categories can be used in assessing stem form.

1	Straight	Ideal for long poles
2	Very minimal crooked	Suitable for long poles
3	Slightly coocked	Suitable for short poles
4	Crooked	Suitable for posts and fuelwoods
5	Very crooked	Suitable as fuelwood only

Assessing Branch Habit

The degree of branching can be assessed using a scale of 1 to 5 with 1 as the best and 5 as the worst. The following categories can be used in assessing branching habit.

1	Straight	Ideal for long poles
2	Very minimal crooked	Suitable for long poles
3	Slightly coocked	Suitable for short poles
4	Crooked	Suitable for posts and fuelwoods
5	Very crooked	Suitable as fuelwood only

A field book is needed for recording data in the field. It should be with hard cover to resist tough handling conditions in the field. The record book must also show the location and site maps. It is ideal to review the entries on the record book at the end of each day of data collection to detect recording errors.

The rule of thumb is to design and establish a field trial in a way that it will permit statistical analysis. Statistical analysis is unnecessary when treatments effects are very obvious that it is easy to accept or reject the hypothesis. However, this is rarely the case. When results cannot be interpreted directly because of overlapping treatment effects, statistical analysis is needed.

FIELD TRIALS ESTABLISHMENTS

Establishing the field trial generally consists of major activities including site selection, site preparation, and plantation establishment, maintenance and protection.

SITE SELECTION

Site selection must be undertaken few months prior to the target period of field trial establishment. It is ideal that the site of the field trial should be homogeneous to avoid variations of results due to differences in site conditions. However, it is rare to find a homogeneous land, hence field trials are usually established in a heterogeneous site. Although the heterogeneity of site conditions is minimised by randomisation and replication of treatments, site selection should aim to identify a field trial site with the least heterogeneity of growth conditions (i.e. soil properties, slope, exposure, and vegetation cover). The site should be accessible, preferably adjacent to road especially of the field trial will also be used as a demonstration and field learning facility. Necessary legal arrangements for the use of the land until the culmination of the experiment should be established to ensure that the field trial will not be destroyed.

A location map should be prepared to provide information about the location of the field trial. This map should provide information including the name of the trial and name of the community. It should also present major location features including roads and tracks, bodies of water, forest, settlements and other physical features that would be useful in finding the field trial. The North direction should be indicated on the location map.

FIELD TRIALS DATA COLLECTION

Measuring base diameter

The base diameter is measured using a caliper positioned on the base of the seedling. It is necessary that subsequent measurements of base diameter will be done on the same point of the stem. Whenever feasible, such point on the stem will be marked for easy identification. Base diameter is usually measured in millimetres.

The diameter at breast height is measured 1.3 meters above the ground. On a sloping ground, the 1.3 meters should be measured on the upper part of the slope. If the stem is forking below the 1.3-meter height, measure the dbh of the forks. A pole 1.3 meters long can be used as guide to locate the dbh line on the stem. When feasible, the dbh line can also be painted for easy identification for subsequent measurements. Dbh is usually recorded in centimetres.

FIELD TRIALS DATA COLLECTION

The set of data that will be collected will depend on the objectives of the field trial. The set of data that will be collected, the collection method and frequency of collection should be decided thoroughly as part of the field trial plan. It is necessary to collect data by replication instead of measuring trees across replicates. It is suggested that at least two individuals will collect the data. One will measure the parameters and the other one as recorder. The number of personnel is increased depending on the magnitude of data that will be collected.

For tree parameters, the following are the usual frequency of assessment:

Parameter	Frequency of measurement
Height	at planting; 3 months; 6 months; 12 months; annual thereafter for five years
Base Diameter	at planting; 3 months; 6 months; 12 months; annual thereafter for five years
Survival	3 months; 6 months; 12 months; annual thereafter for five years
Health	3 months; 6 months; 12 months; annual thereafter for five years
DBH	When tree heights reached 3 meters . measure together with the height
Stem Form	When tree heights reached 3 meters . measure together with the height
Branching habit	When tree heights reached 3 meters . measure together with the height

Measuring seedling and tree height

Height of seedlings are usually measured using a meter stick placed vertically next to the seedling. Seedling height is measured from the base of the seedling up to the tip of the shoot. When seedlings are over a meter tall, a calibrated pole can be used for measuring tree height up to 5 meters. Beyond 5 meters, optical instruments such as a laser hypsometer can be used. Seedling and tree heights are usually measured in centimetres and meters, respectively.

FIELD TRIALS ESTABLISHMENTS

Establishing the field trial generally consists of major activities including site selection, site preparation, and plantation establishment, maintenance and protection.

SITE PREPARATION

Preparing the site typically involves removal of shrubs and trees that would affect the treatments and establishing the field trial layout.

Brushing

Brushing involves removal of vegetation that will adversely affect the results of the trial. Brushing is usually carried out manually using a machete. Burning of slashed vegetation is a common practice but can be avoided if there is a high risk of fire spreading to the entire landscape. Slashed vegetation should be removed and placed outside the experiment blocks.

FIELD TRIALS ESTABLISHMENTS

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SITE PREPARATION

Preparing the site typically involves removal of shrubs and trees that would affect the treatments and establishing the field trial layout.

Laying-out the treatments and replications

Establishment of field trial layout will follow immediately after the area is cleared of shrubs and trees. The layout will show the planting blocks, experiment plots and replications, and the planting points. In establishing the plots, the goal is to minimise the variation across the plots with a replication block. On a sloping ground, the treatment plots should run across the slope while replication blocks are positioned along the slope. The planting points are marked by stakes driven to the ground long enough that they can be seen easily. Wooden posts can be used to mark the corners of each plot and replication blocks. For easy identification, the corner posts of each plot and block will be painted with different colours. Alternatively, coloured ribbons can be used

FIELD TRIALS ESTABLISHMENTS

Establishing the field trial generally consists of major activities including site selection, site preparation, and plantation establishment, maintenance and protection.

PLANTATION ESTABLISHMENT

In the tropics, trees are generally planted in established planting holes rather than in a fully cultivated land. Planting holes should be prepared few days before the planting schedule. A 25 cm x 30 cm hole is ideal to accommodate the entire root system plus ample room to facilitate rapid root development.

Distribute the seedlings on the planting holes according to treatments. Start with Replication 1. Planting will commence once all seedlings have been distributed to the planting points in Replication 1. When the trial involves several species, thorough checking should be carried out to ensure that correct species is placed on the appropriate planting spot. Once the seedlings are distributed and checked, planting will commence. The seedlings must be removed from the container before placing into the planting hole. If poly bags are used, remove the poly bag carefully not to damage the root system and placed on top of the stake that marked the planting point to indicate that seedling on that point has been planted. Place the root system into the hole and cover the roots up to the root collar level using the dug soil from the hole. In covering the root systems, the topsoil should be placed back into the hole followed by the subsoil to provide more nutrients to the rhizosphere. The soil should be pressed to avoid large gaps that hinder the roots from absorbing water and nutrients from the soil

It is ideal to plant the seedlings during the early part of the rainy season. Also, it is best to plant seedlings early in the morning or late in the afternoon. Prepare the seedlings for out planting by watering them thoroughly the day before transporting them from the nursery (or temporary holding area) to the planting site. On the day of out planting, carry the seedlings from the nursery to the planting site using boxes or other containers that will prevent seedling damage. Do not put seedlings on top of each other during transport. Also, it is a mistake to hold a bunch of seedlings on the stem with one hand. Seedlings must be picked up by holding the container instead of the stem or leaves.

FIELD TRIALS ESTABLISHMENTS

Establishing the field trial generally consists of major activities including site selection, site preparation, and plantation establishment, maintenance and protection.

In delineating the blocks, the following steps are suggested:

1. Establishing a straight line corresponding to the longer side (if the block follows a rectangular shape) of the replication block. Designate this as Side 1. The length of Side 1 should include the length of all plots within the replication, which is dictated by the number of seedlings and spacing.

2. Using the compass, measure a 90-degree angle left or right from Side 1, depending on where the experiment block will be oriented. Establish another line following the 90-degree angle from Side 1. Consider this as Side 2.

3. From Side 2, repeat the procedure to establish Side 3.

4. From Side 3, repeat the same procedure to establish Side 4. The four lines will comprise the four sides of the replication block.

5. Adjust lines by moving up or down, left or right, when the end of Side 4 will not meet the start of Side 1. Remember not to reduce or increase the length of the lines when moving the line. Only shift the position, do not alter the length.

6. Once the lines are fixed, mark the corners of the replication block with stakes, driven to the ground such that these can be seen easily but cannot be removed readily. Mark the top 5 cm of the stakes with ribbons or spray paint for easy identification.

7. Mark the corners of the treatment plots with stakes and ribbons or tapes

8. Once the corners of the stakes are marked, begin marking the planting points in each plot. Extend the tape between two corners of Side 1 of Plot 1. Drive a stake on the ground for each of the planting point on the Side 1. Do the same on Side 3. Transfer the tape to connect opposite planting points of Sides 1 and 3 and put stakes on the planting points along the line until all the planting spots in Plot 1 are marked. Continue the process planting points of all plots are marked.

FIELD TRIALS ESTABLISHMENTS

Establishing the field trial generally consists of major activities including site selection, site preparation, and plantation establishment, maintenance and protection.

SITE PREPARATION

Preparing the site typically involves removal of shrubs and trees that would affect the treatments and establishing the field trial layout.

The following are materials necessary in delineating the planting blocks, establishing the experiment plots, and identifying and marking the planting points:

INSTRUMENT	SPECIFICATION	QUANTITY	REMARKS
Sureveyor's Tape	100 m long	2 pcs	Measuring blocks, plots, and planting distance
Compass	Prismatic or surveyor	1 pc	Measuring direction and angle, ensuring square-shaped blocks
Stakes	1 m long, about 10 cm diameter	18 pcs	Marking the corner's of the plots and center of the blocks; can be no longer than 1 m depending on the height of glasses
	50 cm long	800 pcs	Marking the planting points; 400 stakes are needed for each of the two fiels trials
Spray paint	4 colors	2 cans for each colors	Marking the stakes corresponding to each species in the mixed species trial
or			
Ribbon	4 colors	2 rolls of each colors	Marking the stakes corresponding to each species in the mixed species trial
Marking pens	Permanent markers	3 pcs	Bold tip with black ink

ACIAR Project: Enabling Community Forestry in Papua New Guinea (FST 2016- 153)

Commencement Report

Title: Umi Agroforestry Demonstration Plot

Completed by: Clifford S
Date: 16th March, 2018

1.0. Brief Background

The Umi Agroforestry Demonstration Plot (UAD) was established in an Agrisilvicultural system in which combination of trees and cash crops/vegetables was planted in a 0.5ha plot. The aim is to establish an agroforestry system that addresses issues commonly faced by local farmers such as fire, soil nutrients depletion, weed control, low cocoa yield, availability of different food crops all year (short and long term benefits), availability of fuel wood (firewood) and house construction materials.

2.0. Objectives

Establishment of an agroforestry system that;

i. Has fire preventive measures
ii. Encourage soil nutrients conservation
iii. Requires less labor in terms of weed control
iv. Produce continues supply of different foods for personal consumption or for commercial/trade during wet and dry seasons
v. Produce short term and long term benefits for personal consumption or commercial
vi. Provide fuelwood and house construction materials

3.0. Method

3.1. Experimental Design

The total area (100 x 50m) was divided into 3 blocks, block A (40 x 50m), block B (20 x 50m) and block C (40 x 50m). The images below (*Fig 1-4*) show a detail explanation of each block.

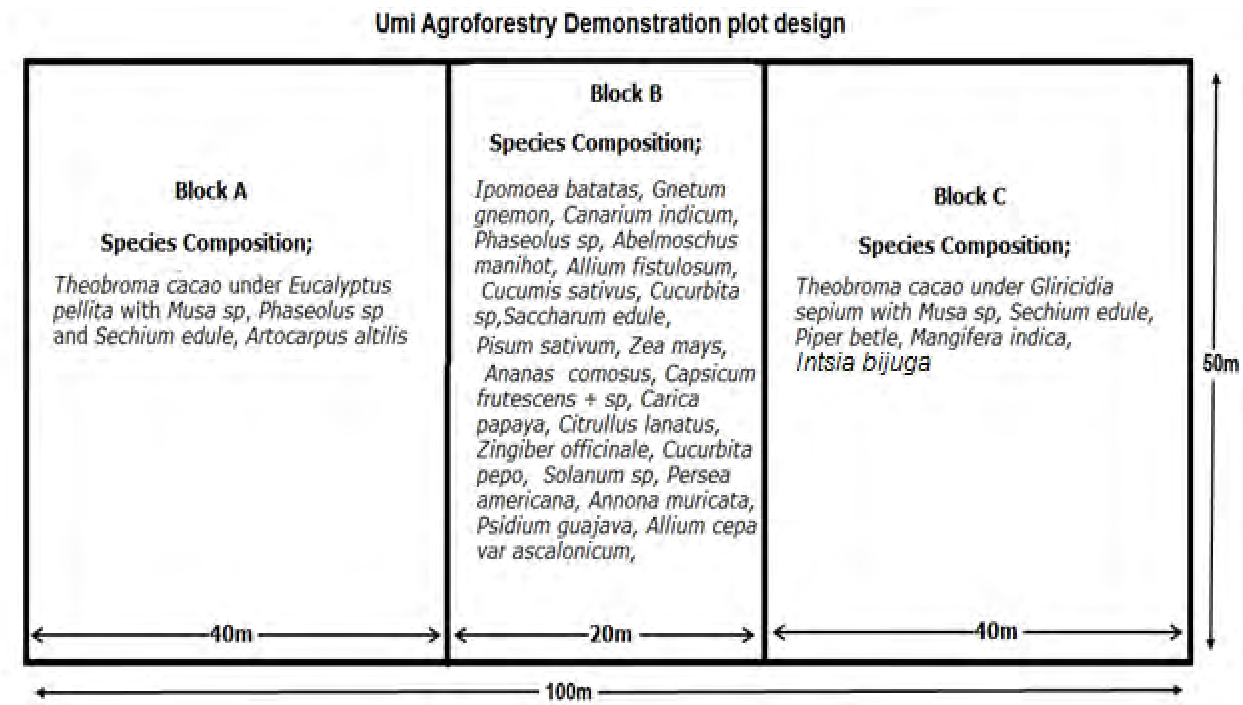


Fig. 1: Image showing Species composition in each Block and the dimensions

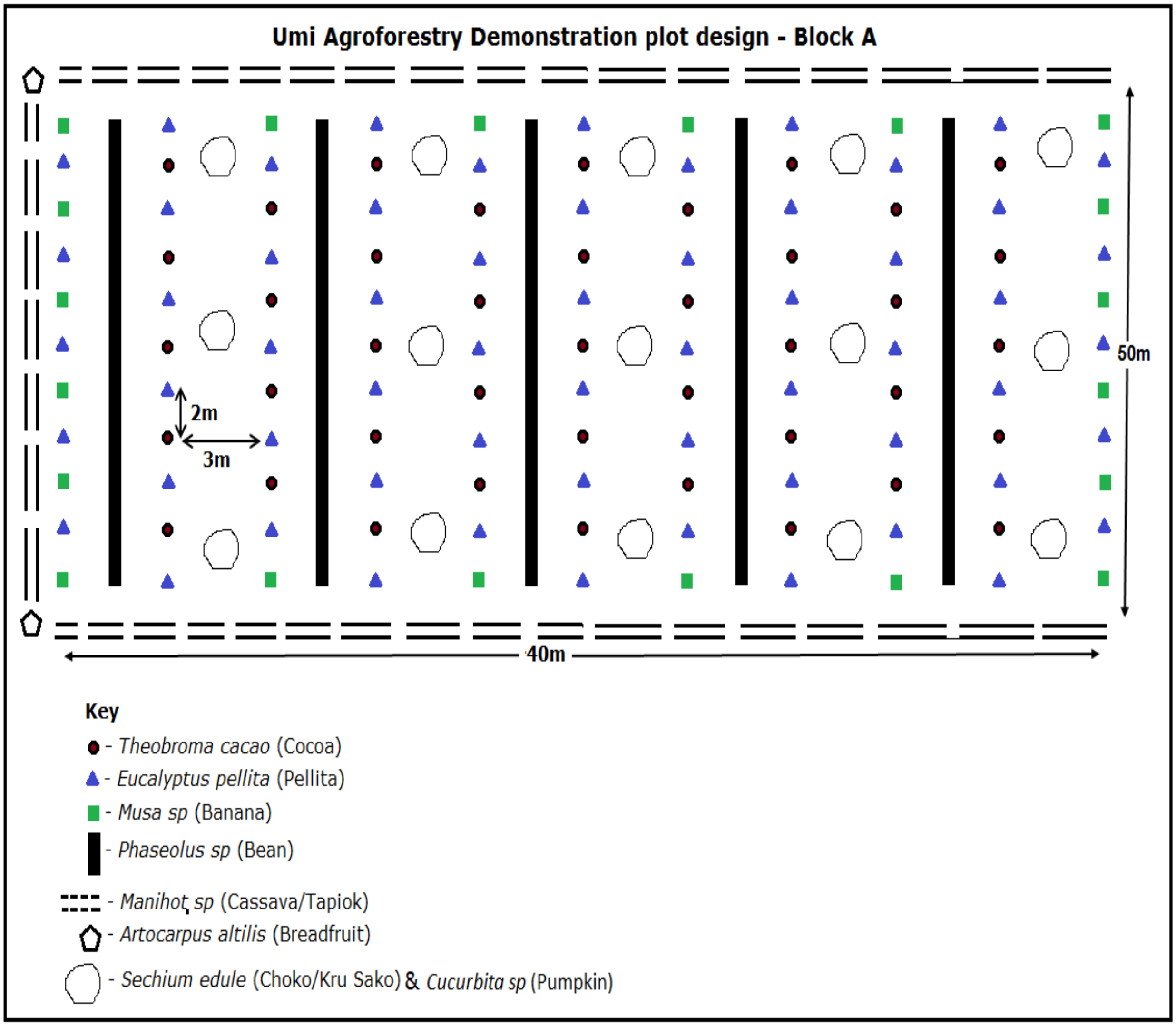


Fig. 2: Image showing the planting design of Block A

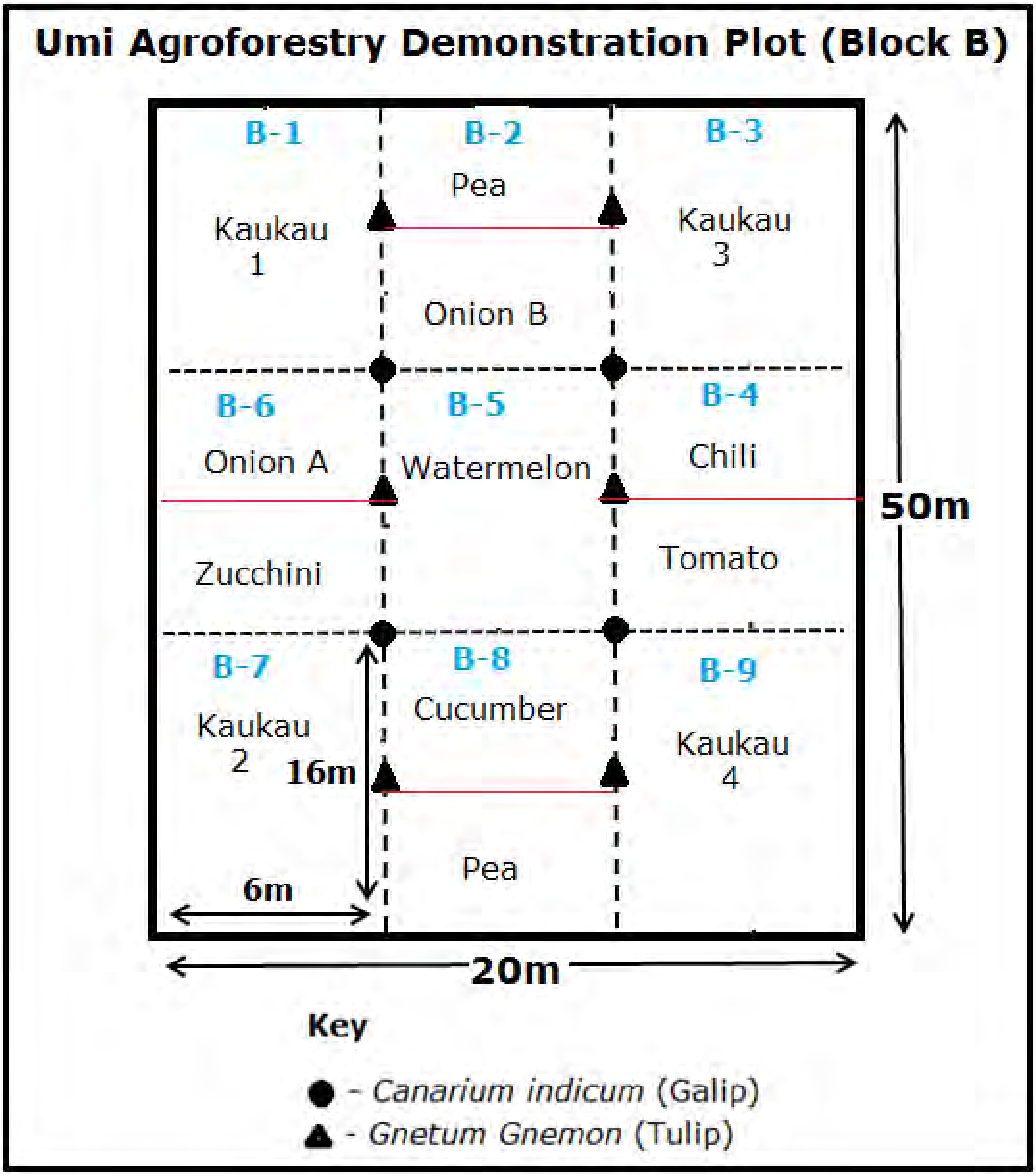


Fig. 3: Image showing the planting design for Block B

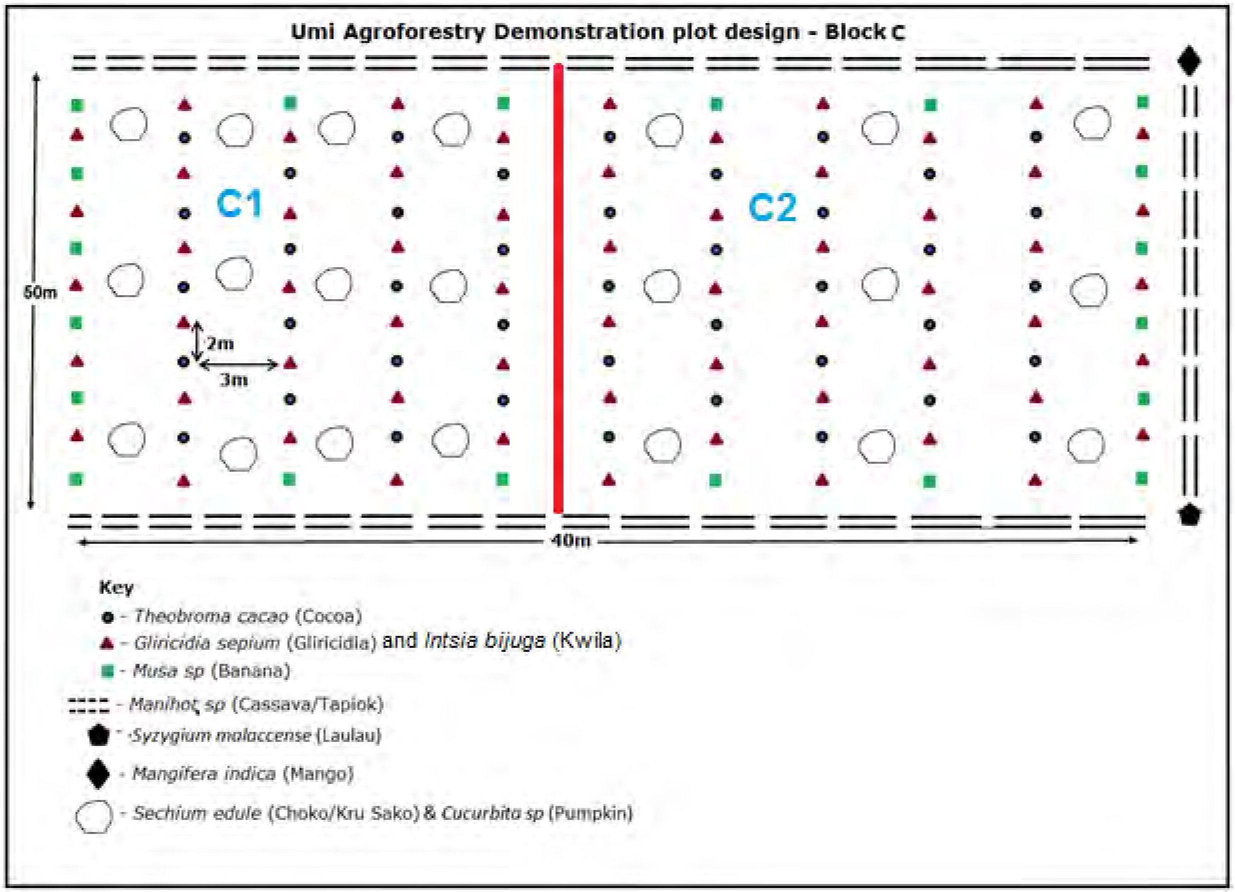


Fig. 4: Image showing the planting design for Block C

Note: Block C was divided in to 2 sub-bock, Block C1 with Gliricidia and C2 with Kwila planted

3.2. Site

The site is located at Umi at coordinates 6°10'54.57"S and 146°10'53.01"E. It is about 60m away from Jennifer Waiko's house and about 47.8 km drive from RAIL Sustainability Office (*Fig. 5*). It's a flat land with sandy loam soil dominated by *Imperata cylindrica*. Annual rainfall is about 1500mm [1].

Fig. 5: Map of the Agroforestry Demo plot

3.3. Stakeholder engagement

A Memorandum of Understanding (MoU) was sign between the ACIAR, RAIL and Jennifer Baing Waiko before any other operation begins. Also interviews were conducted with 3 locals for the position of the Upkeep Attendance of the plot and contract signed with the successful candidate.

3.4. Species selection

All species selected are based on the community preferences survey for Marawasa and Atzunas conducted by Regina Kagl, Nathan Wampe, Melinda Thom & Simon Wanga. Also some are Jennifer's preferences and others are my selection of species which supports the objectives. Below are the species.

Table 1: List of species for the Umi Agroforestry Demonstration plot

No.	Scientific name	Common name
1	*Eucalyptus pellita*	Pellita
2	*Theobroma cacao*	Cocoa
3	*Gliricidia sepium*	Gliricidia
4	*Intsia Bijuga*	Kwila
5	*Cucurbita sp*	Pumpkin
6	*Cucumis sativus*	Cucumber
7	*Canarium indicum*	Galip

8	*Abelmoschus manihot*	Aibika
9	*Manihot esculenta*	Cassava or Tapiok
10	*Piper betle*	Daga
11	*Sechium edule*	Choko or Kru Sako
12	*Ipomoea batatas*	Kaukau
13	*Gnetum gnemon*	Tulip
14	*Saccharum edule*	Lowland Pitpit
15	*Phaseolus vulgaris*	French Bean
16	*Pisum sativum*	Pea
17	*Musa sp*	Banana
18	*Artocarpus altilis*	Breadfruit
19	*Kalanchoe gastonis-bonnieri*	Leaf of Life
20	*Zea mays*	Corn/Maize
21	*Ananas comosus*	Pineapple
22	*Capsicum frutescens + others*	Chili
23	*Carica papaya*	Pawpaw
24	*Citrullus lanatus*	Watermelon
25	*Cucurbita pepo*	Zucchini
26	*Zingiber officinale*	Ginger
27	*Solanum sp*	Tomato
28	*Syzygium malaccense*	Laulau
29	*Persea americana*	Avocado
30	*Annona muricata*	Soursop
31	*Psidium guajava*	Guava
32	*Mangifera indica*	Mango
33	*Allium cepa var ascalonicum*	Onion (Coastal)
34	*Allium fistulosum*	Onion (Highlands)

4.0. Plot Establishment

4.1. Site preparation

The site was demarcated (100m X 50m), weed slashed and soil plowed one week ahead of the planting dates. Large soil chunk were then broken down manually and unwanted roots removed. A local tractor owner was given the contract to conduct the slashing and plowing operation.

4.2. Planting dates

Species such as *Eucalyptus pellita*, *Intsia bijuga*, *Canarium indicum* and *Gnetum Gnemon* was transported to the planting site from the RAIL nursey. Other species such as *Gliricidia sepium, Manihot esculenta, Musa sp, Phaseolus sp, Cucurbit sp*, *Sechium edule, Ipomoea batatas, Zea mays* and others was provided by Jennifer and Jima (Upkeep attendant). Gliricidia growing near Jennifer's house were cut at about 1 meter in height and planted. Jima was advise how and when to plant the different species. Planting dates was according to the design of the plot and the rotation cycle plan.

The table below show the planting dates of the different species.

Table 2: Planting dates of the different species

Scientific name	Common Name	Date planted	Block
Eucalyptus pellita	Pellita	05/12/18	A
Gliricidia sepium	Gliricidia	05/12/18	C1
Intsia bijuga	Kwila	05/12/18	C2
Manihot esculenta	Cassava/Tapiok	18-19/12/18	Boundary
Musa sp	Banana	26-28/12/18	Boundary
Canarium indicum	Galip	28/12/18	B
Gnetum Gnemon	Tulip	28/12/18	B
Phaseolus sp	Bean	10/1/19	A
Phaseolus sp	Bean	10/1/19	B-5
Cucurbita sp	Pumpkin	10/1/19	C
Sechium edule	Choko/Kru Sako	11/1/19	A
Ipomoea batatas	Kaukau (2 different type)	19/01/19	B-1
Ipomoea batatas	Kaukau	5/02/19	B-9
Zea mays	Corn	19/01/19	B (Boundary)
Phaseolus sp	Bean	19/01/19	B (Boundary)
Saccharum edule	Pitpit	20/01/19	B (Boundary)
Cucumis sativus	Cucumber	28/01/19	B-8
Solanum sp	Tomatoes	29/01/9	B-4

Note: The planting date for the cash crops/vegetables were according to the **rotation cycle plan**.

Table 3: Total number of woody perennials species planted

Scientific name	Total number planted
Eucalyptus pellita	67
Intsia bijuga	33
Gliricidia sepium	33
Canarium indicum	4
Gnetum gnemon	6

On the next page are photos of species growing in different Blocks

4.3. Photos

i. Block A

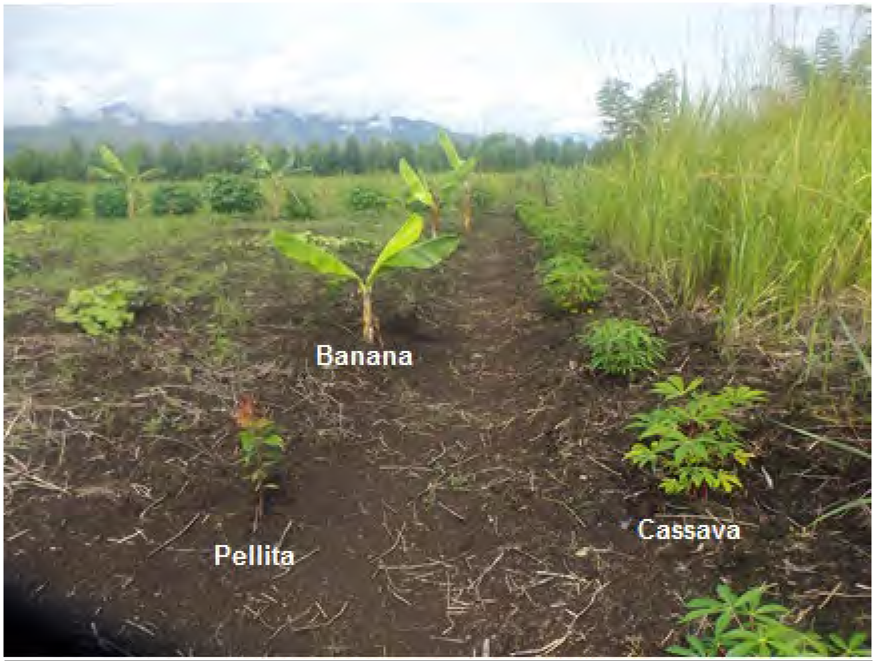


Fig. 6: Pellita intercrop with Banana as Block boundary and Cassava as plot boundary which also act as fire break

Fig. 7: Pellita intercrop with Banana as Block boundary indicating where the plot ends

Fig. 8: Pellita intercrop with Banana as Block boundary separating Block A from Block B

Fig. 9: Bean planted in rows as cover crop to minimize weed and add Nitrogen in Block A

Fig. 10: Pumpkin planted in rows as cover crop to minimize weed in Block A

ii. **Block B**

Fig. 11: First rotation of Sweet Potatoes in Block B and Banana as block boundary marker

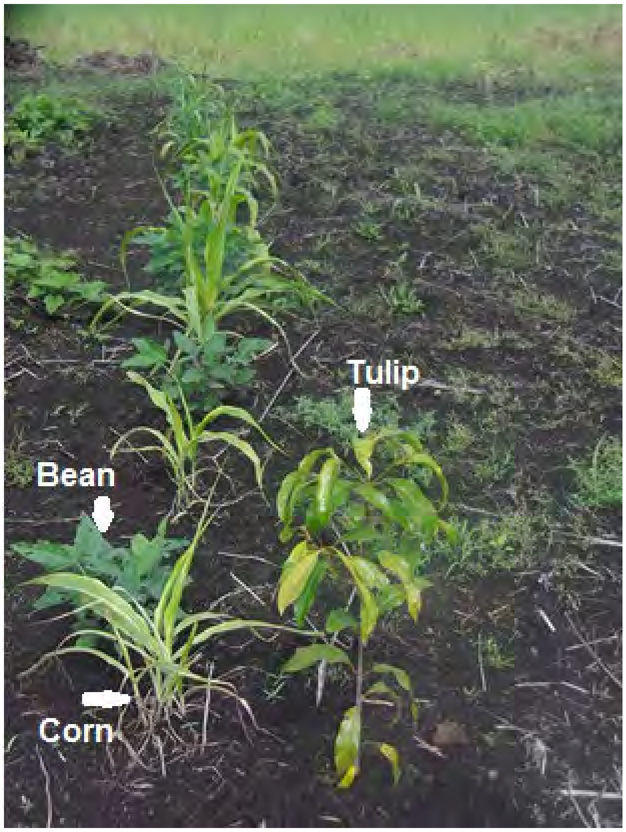


Fig. 12: Corn intercrop with Bean as Sub Block Boundary marker in Block B. Tulip growing well in Block B

Fig. 13: Galip growing well in Block B

iii. **Block C**

Fig. 14: Kwila and Pumpkin in Block C1. Pumpkin as weed control measures

Fig. 15: Block C1 and C2 separated by rows of Pumpkin

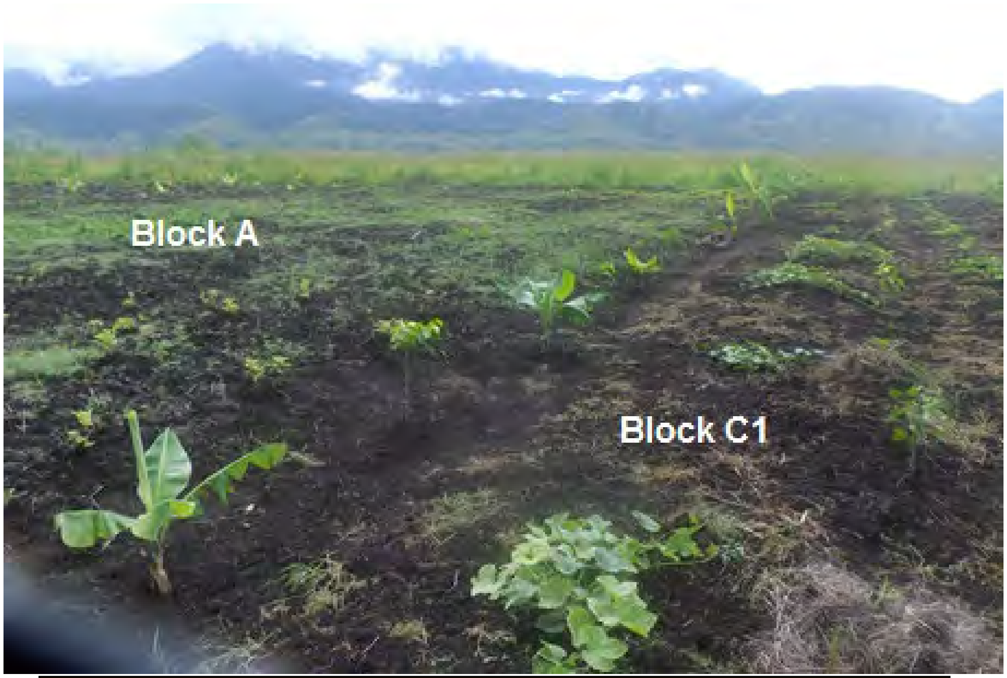


Fig. 16: Block C1 and A separated by rows of Kwila intercrop with Banana

Fig. 17: Cassava as plot boundary marker and fire preventive measures

4.4. Maintenance

Daily maintenance on weed control was carried out by the Upkeep attendant. On two different occasions another two extra helping hand were assign to help with weed control.

5.0. Data collection

Information to be collected are the height and diameter of Pellita, Gliricidia, Galip and Tulip on monthly bases. Protocols are been formulated. As for crops and vegetables, the harvest dates and the total number of fruits produced will be recorded. Forms are already been created. Number of people showing interest were already be recorded.

6.0. Challenges/Problems

i. Weed control at the initial stage during rainy season. Additional helping hands were assign to help with weed control
ii. Control of insect infestation on Pellita and Pumpkin.
iii. Control of the stunt growth of Pumpkin.

Appendices

1. Rotation Cycle Plan & Height + Diameter record form (Attached Excel)

Reference

[1] Remote sensing applications for peanuts in Australia and Papua New Guinea - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Average-rainfall-observed-in-the-Markham-Valley_tbl23_303331422 [accessed 15 Mar, 2019]

Field Report - Goroka

project	**Enabling Community Forestry in Papua New Guinea**
project number	FST/2016/153
Document Type	Agroforestry Establishment Report (03-07 June, 2019)
prepared by	Vincianna Andrew (PNG Forest Authority, Goroka Area Office)
Field Title	Integration of cash crops and multipurpose trees in Ifiufa Village, Goroka District, Eastern Highlands Province.

Contents

1 Aims

1. Integrate multipurpose tree species and assess growth performance.
2. Addressing socio-economic needs through land utilization and maximization.
3. To deduce a viable family agroforestry model.

2 Summary

The family-based preference study on cash crops and tree species undertaken prior to the establishment of the livelihood demonstration trial plot has significance in discovering families' decision on how best tree farming can be integrated within the landscape. With the population pressure, arable land are critical for planning when it comes to land utilization and maximization. These factors were taken into considerations during the establishment of the livelihood demonstration plot. Steven in the Daulo District was the primary target but due to the family's commitment in other activities, the family paid labour for those activities. To save costs for the project, another location was selected instead of the Stevens. This site selected was fertile farmland owned by the Palo family in Ififufa village, Goroka, District.

Three tree species chosen were the pinus *caribeae*, nothafagus *grandis* and swentinia *macrophyll*. The spacing used was 3m between trees and 4m between rows. However, due to the unavailability of the nothafagus seedlings, pinus *caribeae*, and swentinia *macrophyll* were planted on the 2nd of June, 2019. On the mid of September, Anton's visit from FRI added value to the design in donating 70 eaglewood and 35 pelita. This change was incorporated on the Independence weekend, 16th of September. The species included is pelita and eaglewood. The first short term cash crop planted is the Chinese cabbage (limelight) planted after two months of establishment. This short term crop takes about 7weeks before maturity. This has been harvested and sold already.

3 Introduction

Ififa Village is situated out of Goroka Township and it's an half an hour drive from the town. Life in the village is more like in the town where all goods and services are now being paid for money. Even fuelwood and just cleaning around the house are also exchanged for money. This dynamics in traditional way of life to the contemporary life of a rural family also affects the way people perceive forestry and agriculture in their day to day decisions. So to do forestry, the smart way was to get to the people to understand the social dynamics in order to implement the agroforestry demo plot to the best interest and benefit of the family.

The area allocated by the family is a fertile arable land that has been passed down by the father to the son and the son has been using this piece of land for more than a decade. It was planted with coffee trees but due to the effects of climate change, coffee has been giving less to the family. So the father decided that the coffee tree were to be removed and site cleared for the livelihood demonstration plot. The agroforestry demo was gladly accepted by the family by cutting down all the coffee trees and eventually uprooting the smaller trunks. Two local labourers were hired to clear out the planting area with the support of PNGFA casuals.

4 Project Aims & Objectives

The **aim** of the project is to *improve rural livelihoods through family-focused community reforestation and ecoforestry in PNG*. The project has three objectives:

1. Design and test novel tree-based livelihood systems for family-focused community based reforestation.

2. Identify the methods by which family-focused community based reforestation can be scaled-out to a landscape scale.

3. Identify and pilot test institutional arrangements and policy recommendations which improve access to formal timber markets.

5 Progress towards objective 2

5.1. Technical assistance provided by PNGFRI

The livelihood demonstration plot trial design was the first ever design done by me as the project officer. The design of the plot was originally to accommodate three tree species, pinus *caribeae*, nothafagus *grandis* and scwentinia *macrphyll* but due to the unavailability of nothafagus, it was not planted. One hundred (100) mahogany were bought from a private nursery in Lae. The tree species was chosen by the family with citrus over coffee in the demo plot.

Anton came from FRI to assist with the species trial in Matox, Lufa District. After establishment, he visited the agroforestry trial in Ifiufa, Goroka District. He noticed the land was so fertile and suitable for eaglewood so he offered to replace the S. macrophyll and also added Eucalyptus. *pelita.* The amendments done to accommodate the new addition by Anton was gladly accepted by the family because of the added value especially with the eaglewood.

Activities

1) Site Clearance and Preparation

The site selected had no tall grasses except for the coffee trees and few bamboos for clearance. These coffee trees were planted in 2008 but due to climate change, flowering seasons were affected thus resulting in low productivity. So the family decided that, the coffees trees were no longer an economic commodity for them. They agreed to completely clear the coffee trees and try something else. All the coffee trees and bamboos were cleared, debris filed up and burnt within the block with after a week. This was through the assistance of two hired local laborers and the PNGFA staffs.

Brushing and clearance took about 4 days, the next following days were for picket cutting and picketing. The planting baseline, 4m by 3m was measured using a 50m tape measure with the assistance of the compass to square out the plot. The plot size was reduced to 40m x 40m to minimize labour costs and for easy access and management by the family. The 40m x 40m was sub-divided into 3 zones, according to the agroforestry demo plot design.

Figure 1 & 2. Agroforestry Demonstration Site Clearance and Picketing

2) Seedling Production and Transportation

The caribeae seeds were bought from Ramu and raised at the Lapegu PNGFA nursery. Mahogany seedlings were bought and transported from smallholder in Lae. Eaglewood from the FRI nursery and pelita from the PNG Biomass nursery were also transported from Lae. In terms of research, it would be nice to see the performance from all these planting materials from the different nursery sites and compare that of a nursery that will have its own planting material for the next agroforestry trial establishment next year.

3) Selection of Tree Species

The three tree species were selected based on the following significance;

a) Eaglewood as a prominent domesticated agroforestry tree as well as its value,
b) Caribeae for addressing fire resistant seed source in the future for the highlands
c) Pelita for poles as exotic tree species

The next proposed plot will continue with the accommodation of *eaglewood* and *caribeae* with the inclusion of two local species, *nothafagus* and *castapnosis* in a way of giving a competitive environment to the two local species. This will also give the opportunity to see the performance of *eaglewood* and *caribeae* along with the two native species as preferred by the next model family. The nursery activities and management will be offloaded to the community or the family in the next agroforestry trial establishment.

4) Inclusion of Cash Crops and Preference

The notion of including short term cash crops within the trial plot is to address objective 2 in utilizing and maximizing the land to diversifying income generation activities. A seed money in in form of planting materials was given to the family to start with the short term cash crop. The money generated from this will encourage the family to include other short term cash crops for diversification. Different short term cash crops are to be integrated which have different harvesting and marketing seasons to assist the family with income generation. These crops will be continued sowing and harvesting until the medium term cash crop, citrus is planted. The selection of these cash crops are based on the demand and supply chain of the local market based on their observations. The money generated is a means of living for the family in addressing the many socioeconomic needs of the family in the community. This small incentive is the way forward for the project to promote landscape approach in enabling families or communities through the agroforestry concept.

5) Livelihood Demonstration Design

The design accommodated 3 tree species, Aquilaria *crassna,* Pinus *caribeae* and Eucalyptus *pelita*. The planting line between trees is 3m and 4m along the rows. The spacing for the citrus will be 2m between rows of trees and citrus, 3m between rows of trees in the entire plot. A total of 30 citrus will be planted within the 40m x 40m plot. Objective 3 of this demo plot is to utilize and maximize the land to deduce a viable economical agroforestry model, in making use of the space within the plot for the different short term cash crops.

Diagram I: The design of the agroforestry demonstration trial plot in Ifiufa Goroka, Eastern Highlands Province.

AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC	3m	3m	PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			PC	PC	PC	PC	PC
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
AC	AC	AC	AC	AC			EP	EP	EP	EP	EP
		4m							4m		

Trail Summary	**Crops to interplant with trees**	**Variable to assess**
AC = Aquilaria crassna (eaglewood)	1. Limelight chinese cabbage - short rotation	1. Tree height
PC = Pinus caribeae	2. Round cabbage - short rotation	2. Tree diameter
EP = Eucalyptus pellita	3. Citrus - medium crop	3. Productivity of food crops
Spacing: 4 m x 3 m	4. Trees - long term	4. Socioeconomic value (analysis)

The returns from the plot will be analysis using each of the short term cash crops to come up with a viable agroforestry model that can be marketed to families in order to enable more landscape approaches through this model.

6) Establishment

The initial planting was done with just *caribeae* and mahogany but in regular patterns in the four quadrants. The first quadrant was planted with *caribeae* and *mahogany* in each of the planting lines. The second quad with just *caribeae*, and the third quad with *mahogany* and *caribeae*. The last quad with just mahogany. This planting pattern was changed after Anton's visit when he offered the family with eaglewood which the family eagerly accepted. *Mahogany* was replaced with eaglewood with the inclusion of *pelita* in the trial to compensate for the *nothafagus*. The eaglewood took up half of the zones diagonally whilst the other half of the trial was divided again for the mix line planting with *caribeae* and pelita.

Citrus germinate tray has been bought from a local citrus famer and are being raised in the family nursery. These citrus will be cared for maturity until same time next year June, the medium term cash crop will have been planted to fulfill the trial's objective.

Figure 3 & 4. Children and PNGFA nurseryman (Daka) happily planting

7) Productivity of cash crops

The project assisted the farmer with a packet of limelight Chinese cabbage (*Brassica rapa*) and a fertilizer bag at a total cost of K350.00 as a start-up assistance for the short term crop. The notion behind was to motivate the family and improve income avenues in a way to compensate their time invested in the project. This seed money will continue to support its activities in terms of seed purchase and other necessities in maximizing and diversify the income generation activities within the demo plot. The 40m x 40m plot has three diagonal layers and each of these layers are allocated with different short term cash crops planted at different time intervals. The first block was planted with Chinese cabbage (limelight) and has been harvested and sold already. The remaining blocks has been planted with watermelon and cucumber. The harvested block will be replanted with Chinese cabbage (saladia). For each of these short term crops, the productivity, timeframe and cash flow has been recorded for the socioeconomic analysis. Within the time span of six months or so before the integration of the medium term crop (citrus), a cash flow will be drawn to deduce how much can be made from a small piece of land.

Figure 5. Seken Palo and wife at the cabbage trial plot inter-planted with *Pinus caribaea* seedlings.

Figure 6. One of the chosen cash crops raised using empty ice-block plastic

The germinant limelight has been transplanted into empty ice-block cups. Others may see these plastic cups as rubbish but Palo a small authentic model business has made the rubbish into sometime economical. A good example of innovative smallholder family-based agroforestry model to showcase to others.

8) Measurement and Monitoring

Initial height measurement were taken for the tree species, ten of each were randomly taken because of the height differences. This initial height measurement will be compared with the first assessment of the plot after six months. After the six months measurement, it will be annually measured to assess the growth and performance of the tree species which can be recommended to communities and families in the future for other landscape approaches.

Field inspections on the other hand, will be done every end of the month to access the progress of every single cash crop in the plot. Periodic visits by Project partners from USC is also encouraged for encouraging and motivating project field officers and the concerned families as well.

Initial Height Measurement		
No	Species Name	Height (cm)
1	A	96
2	A	77
3	A	40
10	A	70
11	C	26
12	C	23
13	C	50
20	C	25
21	P	26.5
22	P	22
P23	P	24
24	P	30
30	P	32

Table 1: Height measurement taken

6 Recommendations and acknowledgement

Recommendations

Effective monitoring and regular visits by project officer and from fellow project partners from FRI or from the Headquarter is a fundamental key for enabling community forestry approaches in PNG. Also periodic visits from USC would be an advantage to provide technical advice while at the research field sites to encourage and boost moral for field officers to accomplish research activities to achieve the objectives of the project as per the project document. These visits would also keep the families involved in the project motivated and encouraged to continue on the landscape approaches.

Acknowledgement

I would like to thank the Sekan Palo family to fully participate in the establishment of the agroforestry demonstration trial. I also acknowledge the assistance of Anton Lata from FRI for his input in the design and the donation of the 70 eaglewood to the project. Lastly the PNGFA casuals for their assistance in clearing the site.

7 Reference

Vincianna, A. (2019). Agroforestry plot design for family based land utilization and maximization, National Forest Service, PNG Forest Authority, Goroka, Eastern Highlands Province, Papua New Giunea.

8 Followup

8.1 PNGFA Goroka

Warea Andasua

(73429642, wandasua@pngfa.gov.pg)

- Continue to ensure project activities are achieved as planned by the project staff in Goroka.
- Complete establishment report including the management and assessment schedule of the mix species trial.

Vincianna Andrew

(71737008, vandrew@pngfa.gov.pg)

- Establish and manage the agroforestry demo site at Ifiufa
- Continue to work with the lead farmers or ‘champion farmers’ to ensure project activities are achieved.
- Assist in the management and assessment of the trail at Matox.

- Ensure firebreaks and fencing surrounding the trial is completed to prevent domestic animals and people from wandering in the trial site at Matox.
- Liaise with Anton at FRI to develop a design layout for the agroforestry trial.

8.2 FRI

Anton Lata

(74285684, alata@fri.pngfa.gov.pg)

- Provide technical assistance for the agroforestry trial at Ifiufa, Goroka District.
- Assist with preferred seedlings for planting

8.3 USC

Grahame Applegate

(gapplegate@usc.edu.au)

- Visit the research trial sites in Goroka in 2019/2020 onwards.

9 Diary

13 Jun

- Seedling transported from Lae by Warea during PNGFA runs

14 Jun

- Seedling transported from Lapegu extension nursery.

17 – 19 Jun

- Clear felling of coffee trees.
- Continuous clearance of coffee trees and bamboos
- Burning and brushing.

20 Jun

- Picket cutting
- Picketing.
- Establishment (planting of seedlings)

Commencement Report 1- Goroka

project	**Enabling Community Forestry in Papua New Guinea**
project number	FST/2016/153
Document Type	Agroforestry Commencement Report 2 (03-07 June, 2019)
prepared by	Vincianna Andrew (PNG Forest Authority, Goroka Area Office)
Field Title	Agroforestry plot # 2: Integration of trees with food crops in Marasin Bridge Village, Eastern Highlands Province.

Contents

1 Aims

1. Integrate tree species and assess growth performance.
2. To assess if this demo plot is suitable for rural families economically.

2 Summary

The inclusion of a domesticated tree species such as eaglewood adds value to the project where a farmer willingly accepts to adopt the concept without any expenditure involved. As such, the Marasin Bridge plot is different to that of Ifiufa plot because it does not fully maximize the land. The two tree species Pinus *pelita* and Aquilaria *crassna* were the most preferred tree species by the farmer as he assumes Aquilaria *crassna (eaglewood)* has significant value to the land.

3 Introduction

The Mararsin Bridge plot is 15minutes drive from Goroka Township. The area located is within a 20.82ha old coffee plantation that has gone through rehabilitation. The rehabilitation includes, coffee pruning, replanting, brushing, spraying and tree planting. Last year, 12 000 Eucalyptus *grandis* and 3000 Pinus *strobus* were supplied and assisted with the plantings by PNGFA. With the existing rapport, the farmer discovered the eaglewood planted at the Ifiufa demo plot and asked to be the second farmer to establish the other demo plot in his area. This second demo plot is basically integrating trees with a medium term cash crop (coffee) adding to the existing planted trees and coffee in the garden. Food crops will be inter-planted within the plot for the plantation labourers' consumption and this makes the plot here different from the demo plot in Ifiufa.

There is another plot in Kabiufa that has been planted with Eucalyptus *grandis* and coffee already with on perennial or food crops being integrated. So far in terms of diffusion and project impact on the rural families, these different approaches will be monitored and evaluated to recommend to the locals for adoption.

4 Project Aims & Objectives

The **aim** of the project is to *empower the rural population through family-based or community- based agroforestry, reforestation and afforestation in PNG*. The project has three objectives:

1. Design and test novel tree-based livelihood systems for family-focused community based reforestation.

2. Identify the methods by which family-focused community based reforestation can be scaled-out to a landscape scale.

3. Identify and pilot test institutional arrangements and policy recommendations which improve access to formal timber markets.

5 Progress towards objective 2

5.1. Technical input

From the hands on experience from Ifuifa demo plot, there was no holding back on the Marasin Bridge plot. Things flowed smoothly with the site preparation and the plot design for only two tree species, Aquilaria *crassna* and Pinus *pelita*. Thirty (30) eaglewood and a tray of pelita were transported after the MTR in Lae. .

Anton from FRI to assist with the eaglewood inspection for their injection when at six months of establishment as mentioned by him. After the SoE, he will be informed to travel up to Goroka for the due activity after this month so he can inject at both sites (Marasin Bridge and Ifuifa).

Activities

1) Site Clearance and Preparation

The planting site was sprayed with weedicide a week prior to the actual establishment as part of the plantation maintenance. It took a full day for both picketing and planting, with less efforts put in for site clearance and preparation.

The planting area is smaller than that of Ifiufa, 25m x 25m just to utilize the space in the plantation for the eaglewood and pelita. The planting baseline, 4m by 3m was measured using a 50m tape measure with the assistance of the compass to square out the plot. This plot is right in front of the plantation since people commuting the road might uproot and steal the eaglewood.

Figure 1 & 2. Agroforestry demonstration site spraying and picket cutting.

2) **Seedling Transportation**

To enable more family engagement on objective 2, the catch is to give what the farmers' request or prefers. This particular farmer wanted eaglewood and pelita to add to his list so the deal was to bring these two tree species from Lae during the MTR trip. Anton from FRI donated 30 eaglewood and a tray of pelita was negotiated from PNG Biomass nursery transported from Lae to Goroka. The establishment date is 27th of November last year and hence the coffee seedlings will be planted same time this year.

3) Selection of Tree Species

The two tree species selected are based on the following significance;

a) Eaglewood as a prominent domesticated agroforestry tree as well as its value,
b) Pelita for poles and an exotic tree species for agroforestry trial

The fourth family-based agroforestry demo plot will accommodate other tree species rather than eaglewood and pelita being dominant species. This will be the same as Ifuifa to have a clear analysis of the farmer's knowledge and awareness on maximizing and utilizing the land for full return.

4) Livelihood Demonstration Design

The design accommodated 2 tree species, Aquilaria *crassna* and Eucalyptus *pelita*. Planting pattern, a line of eaglewood than a line of pelita by 4m x3m spacing. The spacing for the coffee will be 2m between rows of trees and coffee, 4m between rows of trees in the entire plot. A total of 15 coffee trees will be planted within the 25m x 25m plot.

Diagram I: The design of the agroforestry demonstration trial plot in Marasin Bridge Goroka, Eastern Highlands Province.

4m

AC	AC	AC	AC	AC	AC
AC	AC	AC	AC	AC	AC
AC	AC	AC	AC	AC	AC
AC	AC	AC	AC	AC	AC
AC	AC	AC	AC	AC	AC
EP	EP	EP	EP	EP	EP
EP	EP	EP	EP	EP	EP
EP	EP	EP	EP	EP	EP
EP	EP	EP	EP	EP	EP

3m

Trail Summary	**Food crops to interplant with trees**	**Variable to assess**
AC = Aquilaria crassna (eaglewood) EP = Eucalyptus pellita Spacing: 4 m x 3 m	1. Corn 2. Beans 3. Coffee - medium term 4. Trees - long term	1. Tree height 2. Tree diameter 3. Coffee growth performance

The returns from the medium term crop (coffee) will be analysis using each seasons of coffee to see if it's worth integrating coffee with trees or the holistic approach on land maximization economically viable for family-based landscape approaches. The more return on a piece of land will be determined by the farmer's decision to maximize the land or not. One other factor is the availability of fertile farm land that affects the size of the plot as in Marasin Bridge.

5) Establishment

The

Citrus germinate tray has been bought from a local citrus famer and are being raised in the family nursery. These citrus will be cared for maturity until same time next year June, the medium term cash crop will have been planted to fulfill the trial's objective.

Figure 3 & 4. Farmer Manu Ijape (businessman) planting eaglewood in the plot.

6) Measurement and Monitoring

Initial height measurement were taken. Five of each tree species were randomly taken due to height differences. This initial height measurement will be compared with the first assessment of the plot after six months. After the six months measurement, it will be annually measured to assess the growth and performance of the tree species which can be recommended to communities and families in the future for other landscape approaches.

Field inspections on the other hand, will be done every end of the month to access the progress of every single cash crop in the plot. Periodic visits by Project partners from USC is also encouraged for encouraging and motivating project field officers and the concerned families as well.

Initial Height Measurement		
No	Species Name	Height (cm)
1	AC	42
2	AC	60
3	AC	38
4	AC	30
5	AC	26
6	EP	23
7	EP	20
8	EP	25
9	EP	19
10	EP	27

Table 1: Height measurement taken.

6 Recommendations and acknowledgement

Recommendations

Effective monitoring and regular visits by project officer and from fellow project partners from FRI or from the Headquarter is a fundamental key for enabling community forestry approaches in PNG. Also periodic visits from USC would be an advantage to provide technical advice to project officers on sites for encouragement to accomplish research activities, meeting expected outcomes as per the project document. These visits would also keep the families involved in the project motivated and encouraged to continue on the landscape approaches.

Acknowledgement

I would like to thank Manu Ijape to fully participate in the establishment of the agroforestry demonstration trial. I also acknowledge the assistance of Anton Lata from FRI and PNG Biomass for the donation of the seedlings. Lastly, the PNGFA casuals for their assistance in picketing and planting.

7 Follow-up

7.1 PNGFA Goroka

Warea Andasua

(73429642, wandasua@pngfa.gov.pg)

- Continue to ensure project activities are achieved as planned by the project staff in Goroka.
- Complete establishment report including the management and assessment schedule of the mix species trial.

Vincianna Andrew

(71737008, vandrew@pngfa.gov.pg)

- Establish and manage the agroforestry demo sites
- Continue to work with the lead farmers or ‘champion farmers’ to ensure project activities are achieved.
- Assist in the management and assessment of the trial at Matox.
- Ensure firebreaks and fencing surrounding the trial is completed to prevent domestic animals and people from wandering in the trial sites.
- Negotiate with Anton at FRI for eaglewood and pelita from PNG Biomass for refilling.

7.2 FRI

Anton Lata

(74285684, alata@fri.pngfa.gov.pg)

- Provide technical assistance for the agroforestry trial at Ifiufa, Goroka District.
- Assist with preferred seedlings for planting

7.3 USC

Grahame Applegate

(gapplegate@usc.edu.au)

- Visit the research trial sites in Goroka in 2019/2020 onwards.

9 Diary

24 Nov

- Seedling transported from Lae by Vincianna after MTR

25 Nov

- Site Inspection and delivery of planting materials to site.

26 Nov

- Picket cutting.
- Picketing
- Planting.

Demonstration Site Design

The design of the site utilizes three blocks; Block A, Block B, and Block C. Blocks A and C have a primary focus of cocoa production, with a total of 232 *Theobroma cacao* (cocoa) trees. Both blocks have a border of *Manihot* sp. (cassava) plants and a border of *Musa* sp. (banana)/shade trees to act a buffer against fires. The shade tree species in Block A are *Eucalyptus pellita* (Eucalyptus), which were selected for their use as a fuelwood and for home construction materials. The shade tree species in Block B is split between *Gliricidia sepium* (Gliricidia) and *Intsia bijuga* (Kwila). *Gliricidia sepium* was selected for its ease of establishment and nitrogen fixing properties. *Intsia bijuga* is a high-value timber species, but it does not grow well in an open-sun/plantation environment. It was selected to demonstrate that it should not be used as a shade-crop tree, despite the interest in its use by local landowners. The trees in Blocks A and C are intercropped with *Cucurbita* sp. (pumpkin), *Phaseolus* sp. (beans), and *Sechium edule* (choko) to aid in weed control, nitrogen fixation, and the provision of additional crop income.

Block B has a primary focus of agricultural production. The main agricultural crop is *Ipomoea batatas* (sweet potato), which is grown in a sub-plot with *Zea mays* (corn). The sweet potato and corn sub-plot is grown at staggered intervals in each of the four corner sub-plots in Block B. The remaining agricultural crops are; *Citrullus lanatus* (watermelon), *Solanum* sp. (tomato), *Capsicum* sp. (chili pepper), *Allium fistulosum* (spring onion), and *Abelmoschus manihot* (aibika). Each of these remaining crops has an adjacent sub-plot that lies fallow every other year and is planted with *Phaseolus* sp. (beans). Block B also incorporates two tree species; *Canarium indicum* (Galip) for nut production, and *Gnetum gnemon* (Tulip) to produce leafy greens.

Background Information

The Umi agroforestry demonstration site was established as an agri-silvicultural system. A combination of trees and cash crops/vegetables were planted in a one-half hectare plot. The aim of this demonstration site is the establishment of an agroforestry system that addresses issues commonly faced by local farmers such as fire control, soil nutrient depletion, weed control, low cocoa yield, availability of different food crops year-round, the availability of fuel wood (firewood), and the provision of house construction materials. The site is located in the Ramu Valley, at coordinates 6°10’54.57”S and 146°10’53.01”E. The species selected for the site were based on a community preference survey, conducted in the Marawasa and Atunas communities.

Early growth - February 2019

Banana and Eucalyptus - February 2020

Australian Government

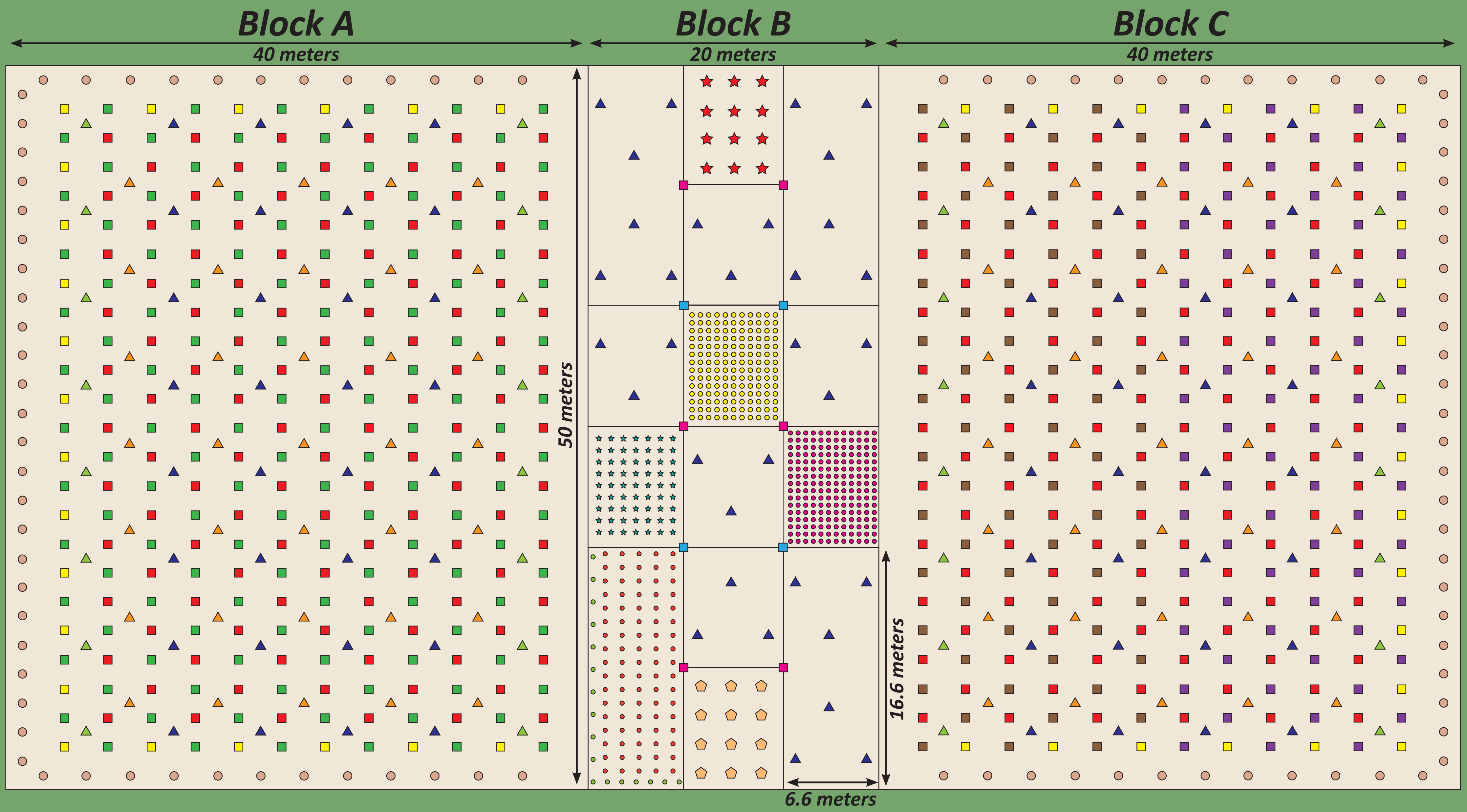
Australian Centre for International Agricultural Research

Umi Agroforestry Demonstration Site

April, 2020

ACIAR Project FST-2016-153

ACIAR



Tree Crops

Theobroma cacao (Cocoa)	232
Gnetum gnemon (Tulip)	6
Musa sp. (Banana)	44
Eucalyptus pellita (Eucalyptus)	137
Canarium indicum (Galip)	4
Gliricidia sepium (Gliricidia)	68
Intsia bijuga (Kwila)	69

Vegetable Crops

Manihot sp. (Cassava)	96
Ipomoea batatas (Sweet potato)	85
Zea mays (Corn)	17
Allium fistulosum (Spring onion)	192
Solanum sp. (Tomato)	154
Cucurbita sp. (Pumpkin)	70
Sechium edule (Choko)	16
Phaseolus sp. (Bean)	97
Abelmoschus manihot (Aibika)	7
Capsicum sp. (Chili pepper)	63
Citrullus lanatus (Watermelon)	12

ACIAR Project: Enabling Community Forestry in Papua New Guinea (FST 2016- 153)

Commencement Report

Title: Umi Agroforestry Demonstration Plot

Completed by: Clifford S
Date: 16th March, 2018

1.0. Brief Background

The Umi Agroforestry Demonstration Plot (UAD) was established in an Agrisilvicultural system in which combination of trees and cash crops/vegetables was planted in a 0.5ha plot. The aim is to establish an agroforestry system that addresses issues commonly faced by local farmers such as fire, soil nutrients depletion, weed control, low cocoa yield, availability of different food crops all year (short and long term benefits), availability of fuel wood (firewood) and house construction materials.

2.0. Objectives

Establishment of an agroforestry system that;

i. Has fire preventive measures
ii. Encourage soil nutrients conservation
iii. Requires less labor in terms of weed control
iv. Produce continues supply of different foods for personal consumption or for commercial/trade during wet and dry seasons
v. Produce short term and long term benefits for personal consumption or commercial
vi. Provide fuelwood and house construction materials

3.0. Method

3.1. Experimental Design

The total area (100 x 50m) was divided into 3 blocks, block A (40 x 50m), block B (20 x 50m) and block C (40 x 50m). The images below (*Fig 1-4*) show a detail explanation of each block.

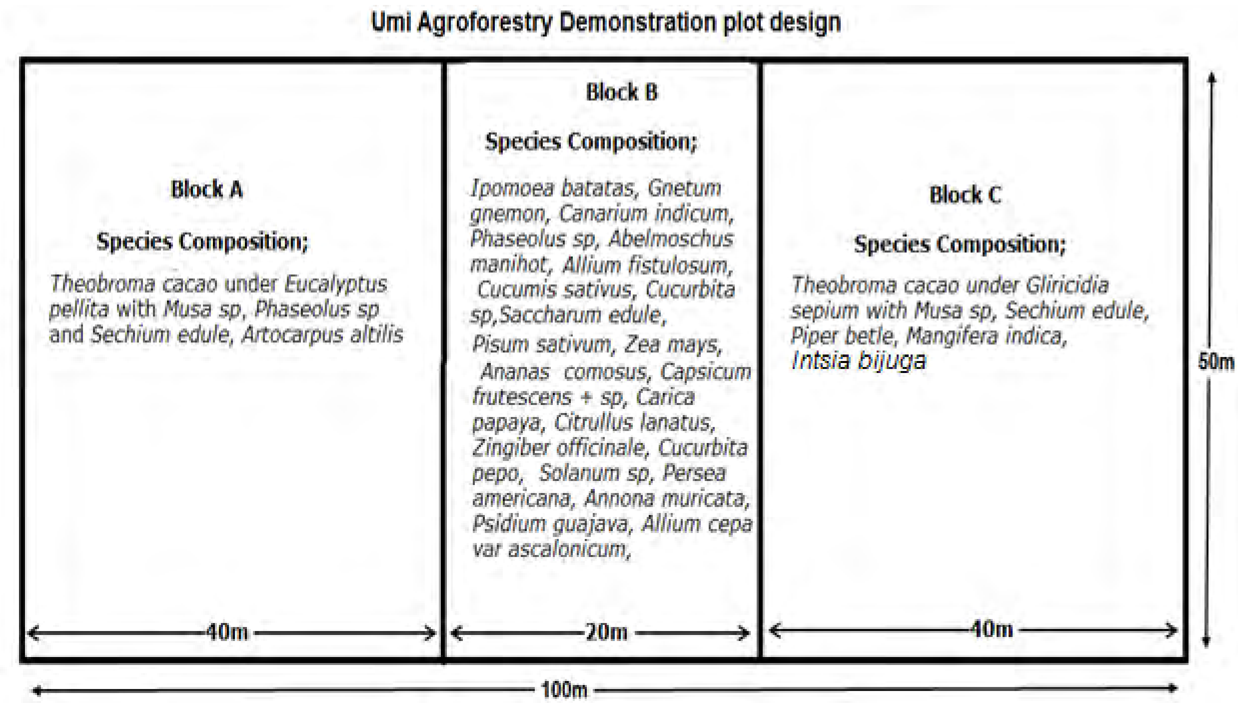


Fig. 1: Image showing Species composition in each Block and the dimensions

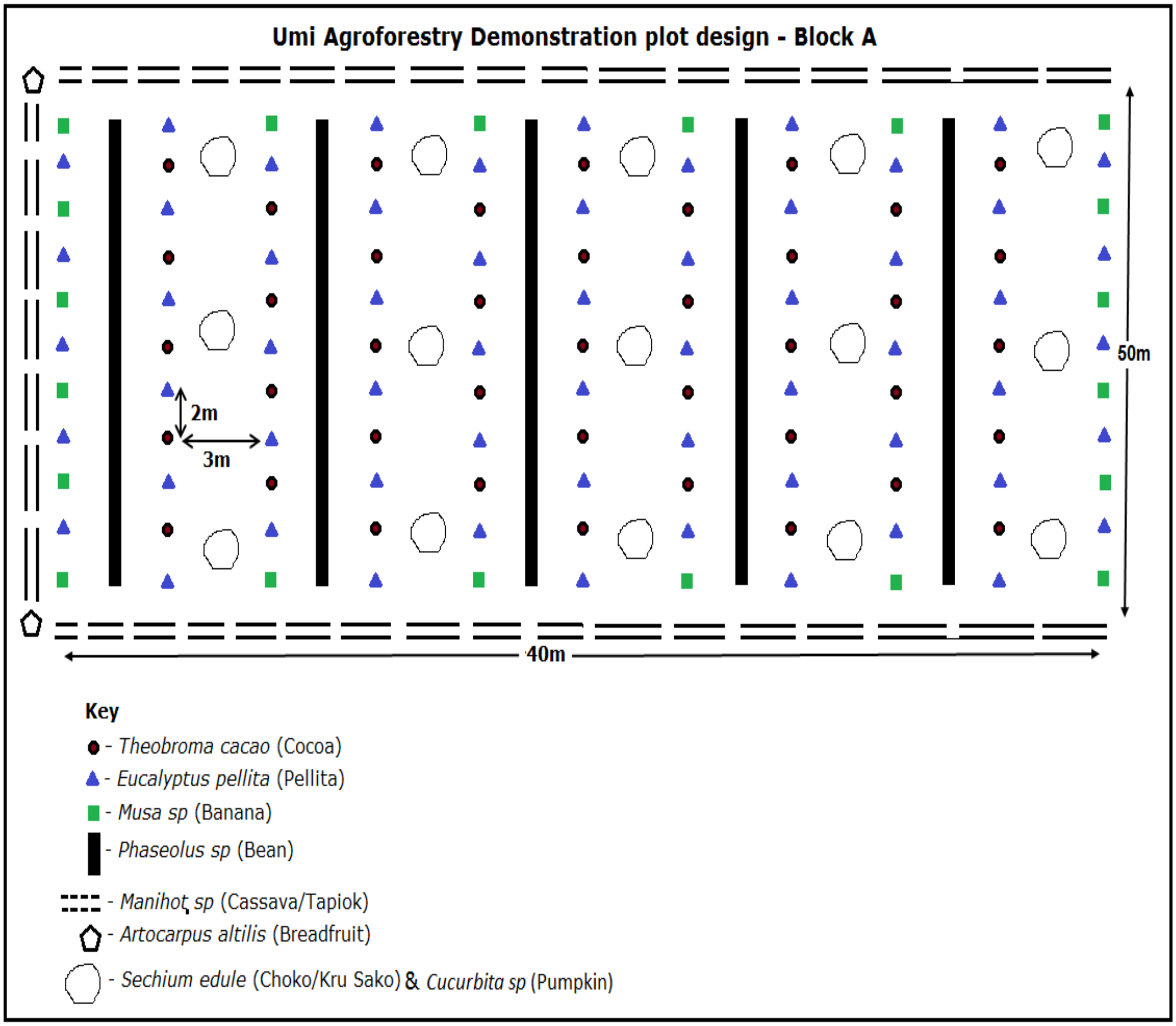


Fig. 2: Image showing the planting design of Block A

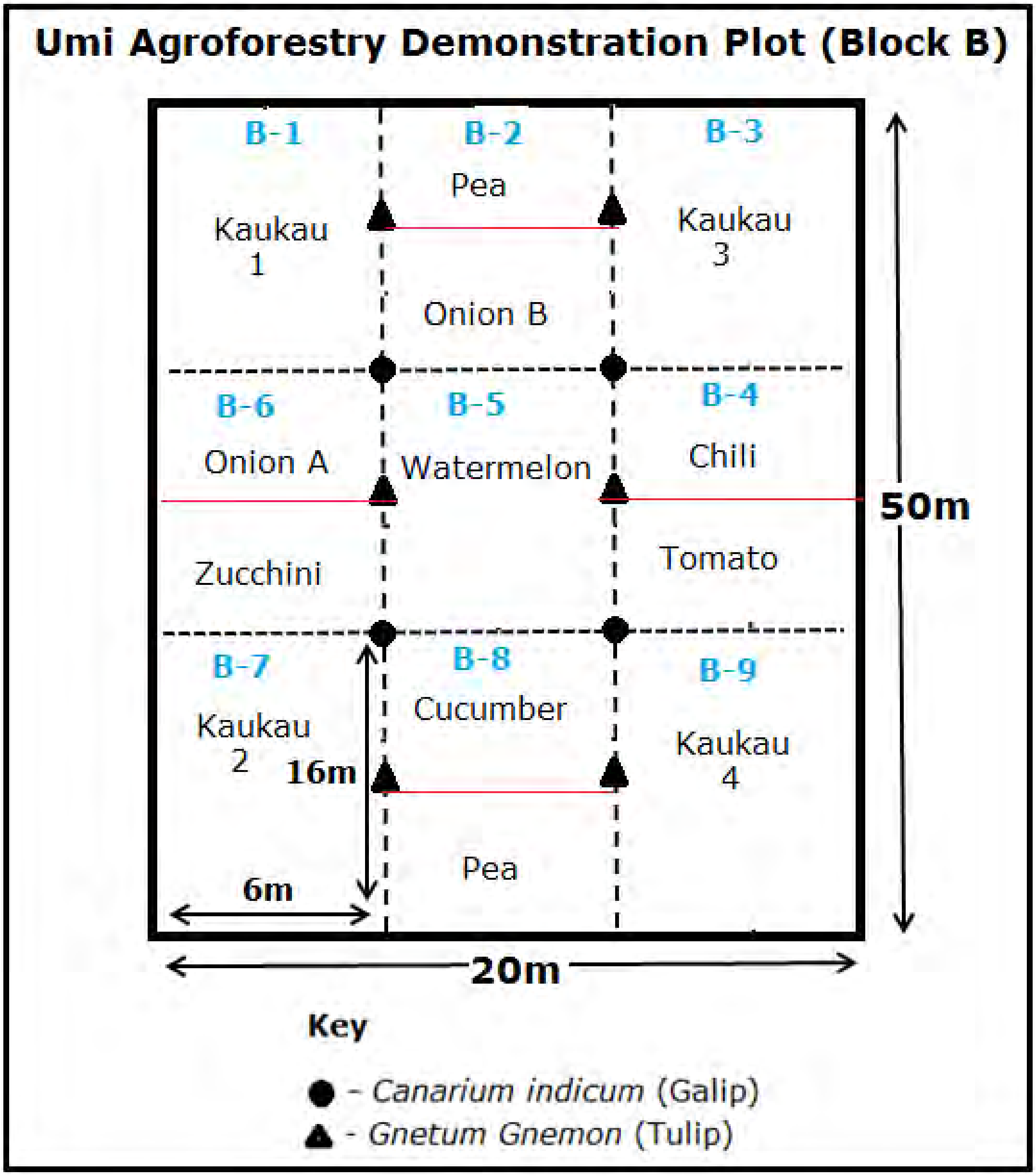


Fig. 3: Image showing the planting design for Block B

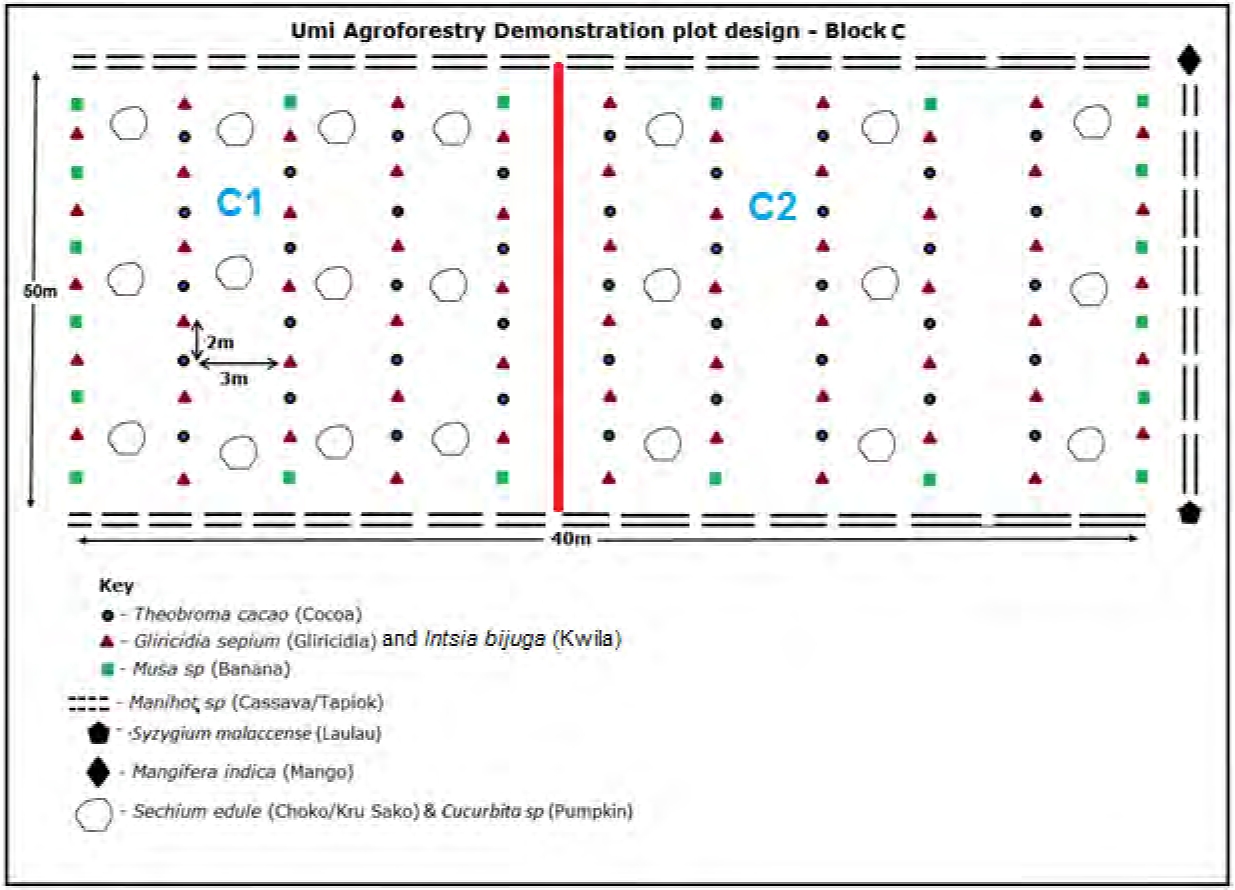


Fig. 4: Image showing the planting design for Block C

Note: Block C was divided in to 2 sub-bock, Block C1 with Gliricidia and C2 with Kwila planted

3.2. Site

The site is located at Umi at coordinates 6°10'54.57"S and 146°10'53.01"E. It is about 60m away from Jennifer Waiko's house and about 47.8 km drive from RAIL Sustainability Office (*Fig. 5*). It's a flat land with sandy loam soil dominated by *Imperata cylindrica*. Annual rainfall is about 1500mm [1].

Fig. 5: Map of the Agroforestry Demo plot

3.3. Stakeholder engagement

A Memorandum of Understanding (MoU) was sign between the ACIAR, RAIL and Jennifer Baing Waiko before any other operation begins. Also interviews were conducted with 3 locals for the position of the Upkeep Attendance of the plot and contract signed with the successful candidate.

3.4. Species selection

All species selected are based on the community preferences survey for Marawasa and Atzunas conducted by Regina Kagl, Nathan Wampe, Melinda Thom & Simon Wanga. Also some are Jennifer's preferences and others are my selection of species which supports the objectives. Below are the species.

Table 1: List of species for the Umi Agroforestry Demonstration plot

No.	Scientific name	Common name
1	*Eucalyptus pellita*	Pellita
2	*Theobroma cacao*	Cocoa
3	*Gliricidia sepium*	Gliricidia
4	*Intsia Bijuga*	Kwila
5	*Cucurbita sp*	Pumpkin
6	*Cucumis sativus*	Cucumber
7	*Canarium indicum*	Galip

8	*Abelmoschus manihot*	Aibika
9	*Manihot esculenta*	Cassava or Tapiok
10	*Piper betle*	Daga
11	*Sechium edule*	Choko or Kru Sako
12	*Ipomoea batatas*	Kaukau
13	*Gnetum gnemon*	Tulip
14	*Saccharum edule*	Lowland Pitpit
15	*Phaseolus vulgaris*	French Bean
16	*Pisum sativum*	Pea
17	*Musa sp*	Banana
18	*Artocarpus altilis*	Breadfruit
19	*Kalanchoe gastonis-bonnieri*	Leaf of Life
20	*Zea mays*	Corn/Maize
21	*Ananas comosus*	Pineapple
22	*Capsicum frutescens + others*	Chili
23	*Carica papaya*	Pawpaw
24	*Citrullus lanatus*	Watermelon
25	*Cucurbita pepo*	Zucchini
26	*Zingiber officinale*	Ginger
27	*Solanum sp*	Tomato
28	*Syzygium malaccense*	Laulau
29	*Persea americana*	Avocado
30	*Annona muricata*	Soursop
31	*Psidium guajava*	Guava
32	*Mangifera indica*	Mango
33	*Allium cepa var ascalonicum*	Onion (Coastal)
34	*Allium fistulosum*	Onion (Highlands)

4.0. Plot Establishment

4.1. Site preparation

The site was demarcated (100m X 50m), weed slashed and soil plowed one week ahead of the planting dates. Large soil chunk were then broken down manually and unwanted roots removed. A local tractor owner was given the contract to conduct the slashing and plowing operation.

4.2. Planting dates

Species such as *Eucalyptus pellita*, *Intsia bijuga*, *Canarium indicum* and *Gnetum Gnemon* was transported to the planting site from the RAIL nursey. Other species such as *Gliricidia sepium, Manihot esculenta, Musa sp, Phaseolus sp, Cucurbit sp*, *Sechium edule, Ipomoea batatas, Zea mays* and others was provided by Jennifer and Jima (Upkeep attendant). Gliricidia growing near Jennifer's house were cut at about 1 meter in height and planted. Jima was advise how and when to plant the different species. Planting dates was according to the design of the plot and the rotation cycle plan.

The table below show the planting dates of the different species.

Table 2: Planting dates of the different species

Scientific name	Common Name	Date planted	Block
Eucalyptus pellita	Pellita	05/12/18	A
Gliricidia sepium	Gliricidia	05/12/18	C1
Intsia bijuga	Kwila	05/12/18	C2
Manihot esculenta	Cassava/Tapiok	18-19/12/18	Boundary
Musa sp	Banana	26-28/12/18	Boundary
Canarium indicum	Galip	28/12/18	B
Gnetum Gnemon	Tulip	28/12/18	B
Phaseolus sp	Bean	10/1/19	A
Phaseolus sp	Bean	10/1/19	B-5
Cucurbita sp	Pumpkin	10/1/19	C
Sechium edule	Choko/Kru Sako	11/1/19	A
Ipomoea batatas	Kaukau (2 different type)	19/01/19	B-1
Ipomoea batatas	Kaukau	5/02/19	B-9
Zea mays	Corn	19/01/19	B (Boundary)
Phaseolus sp	Bean	19/01/19	B (Boundary)
Saccharum edule	Pitpit	20/01/19	B (Boundary)
Cucumis sativus	Cucumber	28/01/19	B-8
Solanum sp	Tomatoes	29/01/9	B-4

Note: The planting date for the cash crops/vegetables were according to the **rotation cycle plan**.

Table 3: Total number of woody perennials species planted

Scientific name	Total number planted
Eucalyptus pellita	67
Intsia bijuga	33
Gliricidia sepium	33
Canarium indicum	4
Gnetum gnemon	6

On the next page are photos of species growing in different Blocks

4.3. Photos

i. Block A

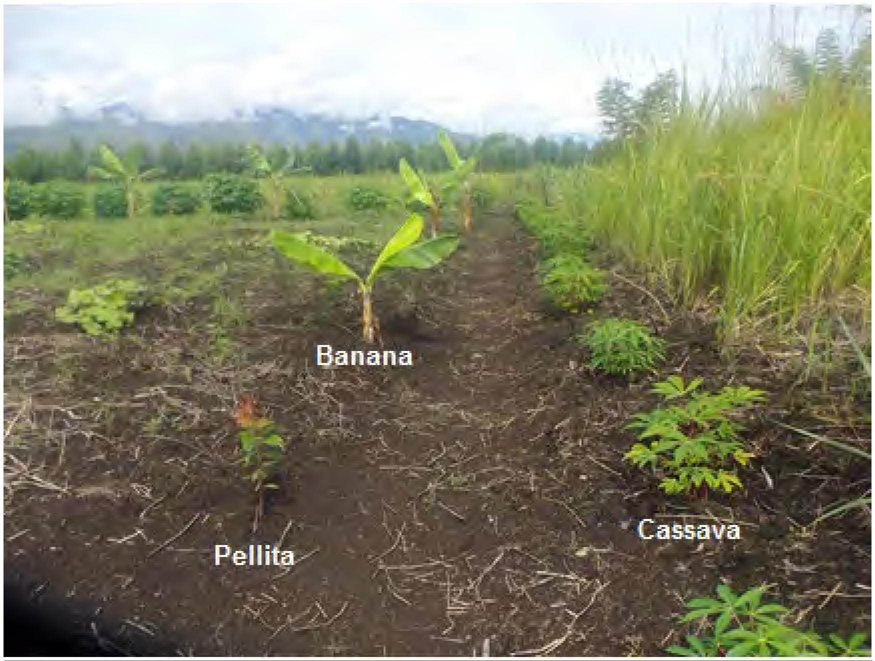


Fig. 6: Pellita intercrop with Banana as Block boundary and Cassava as plot boundary which also act as fire break

Fig. 7: Pellita intercrop with Banana as Block boundary indicating where the plot ends

Fig. 8: Pellita intercrop with Banana as Block boundary separating Block A from Block B

Fig. 9: Bean planted in rows as cover crop to minimize weed and add Nitrogen in Block A

Fig. 10: Pumpkin planted in rows as cover crop to minimize weed in Block A

ii. **Block B**

Fig. 11: First rotation of Sweet Potatoes in Block B and Banana as block boundary marker

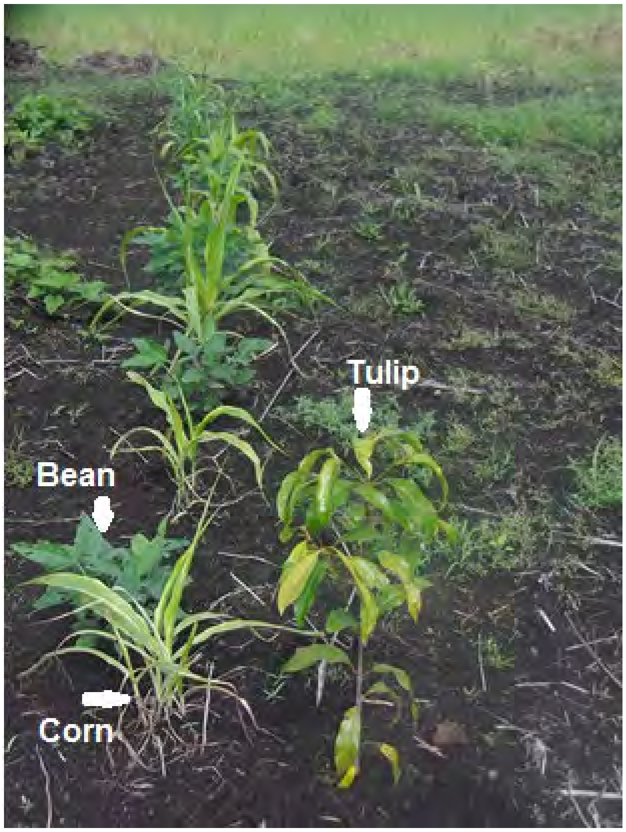


Fig. 12: Corn intercrop with Bean as Sub Block Boundary marker in Block B. Tulip growing well in Block B

Fig. 13: Galip growing well in Block B

iii. **Block C**

Fig. 14: Kwila and Pumpkin in Block C1. Pumpkin as weed control measures

Fig. 15: Block C1 and C2 separated by rows of Pumpkin

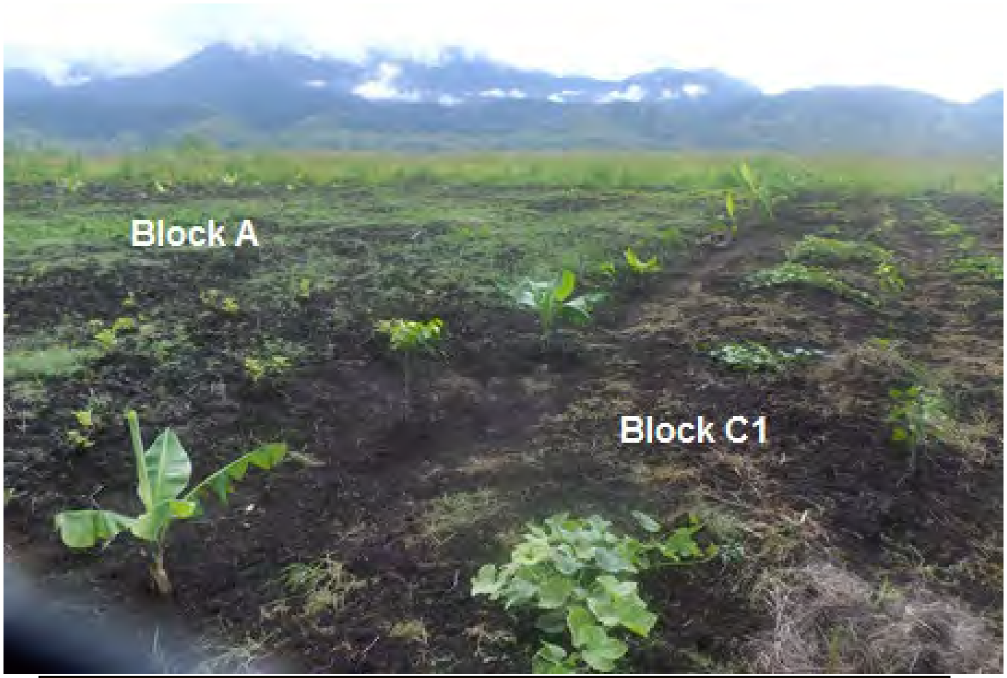


Fig. 16: Block C1 and A separated by rows of Kwila intercrop with Banana

Fig. 17: Cassava as plot boundary marker and fire preventive measures

4.4. Maintenance

Daily maintenance on weed control was carried out by the Upkeep attendant. On two different occasions another two extra helping hand were assign to help with weed control.

5.0. Data collection

Information to be collected are the height and diameter of Pellita, Gliricidia, Galip and Tulip on monthly bases. Protocols are been formulated. As for crops and vegetables, the harvest dates and the total number of fruits produced will be recorded. Forms are already been created. Number of people showing interest were already be recorded.

6.0. Challenges/Problems

i. Weed control at the initial stage during rainy season. Additional helping hands were assign to help with weed control
ii. Control of insect infestation on Pellita and Pumpkin.
iii. Control of the stunt growth of Pumpkin.

Appendices

1. Rotation Cycle Plan & Height + Diameter record form (Attached Excel)

Reference

[1] Remote sensing applications for peanuts in Australia and Papua New Guinea - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Average-rainfall-observed-in-the-Markham-Valley_tbl23_303331422 [accessed 15 Mar, 2019]

Enabling Community Approaches in Papua New Guinea

Lessons Learnt while engaging with ACIAR FST/2016/153: Eastern Highlands Province, PNG

Presenter: Vincianna Andrew

Presentation Outline

- ➢Overview of Community engagement & participation
- ➢Activities carried out
- ➢Achievements/highlights
- ➢Challenges
- ➢Possible solutions
- ➢Conclusion

Overview of project activities

Expected project output		
Activity Type	Quantity	Output
Community-based reforestation	2	2
Agroforestry Livelihood Demonstration plot	2	1
Community-based Q-seedling Training	2	2
Follow-up survey	2 round trips	NA

Community-based Q-seedling Trainings

Daulo Cooperative Q-seedling Training

- 20 Daulo Cooperative members
- Selection of members

Atra Hapa Community-based Q-seedling Training

- 6 grassland communities identified
- Written invite to community prior training
- Only 5 communities attended

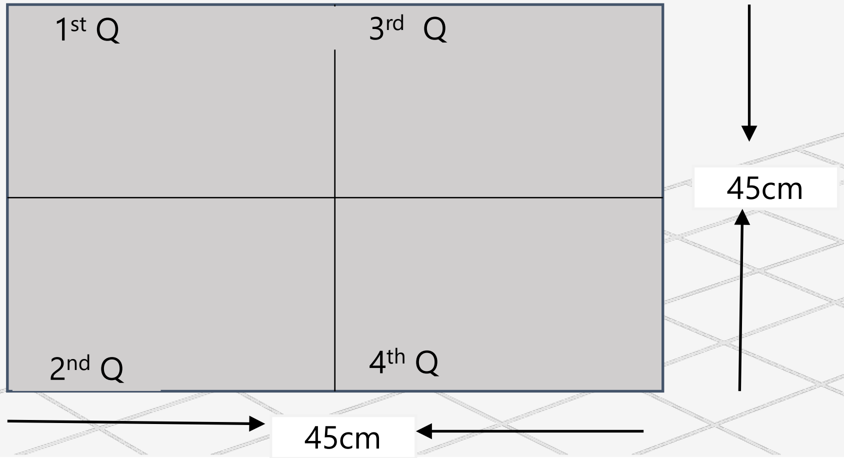
Ifiufa Livelihood Demonstration Plot

Establishment-based on farmer's preference

Cleared arable coffee plot for demo plot

ACIAR Project, establishment cost & K380 seed capital

Species composition eaglewood/carribea/pellita/magohony



Community-based Afforestation/reforestation

Atra Hapa Clan-based Afforestation planting

Interested Clan identified and engaged in afforestation planting

Busbata Clan-based Planting

Planting in rememberance late Mr Arinaso Pilisi

Achievements

Completion of;

2X Community-based training

2X Community-based afforestation

1X Demo Agroforestry Plot

Counter fund assistance from PNGFA

Challenges and possible recommendations

Lack of commit from clan members – requires regular visitation for motivation

Fire threat – continue with fire resistant tree species as such P. ocarpa or carribea

Farmers are often isolated – good to engage all stakeholders from the initial stage, especially influential figures & farmers

Carry out all activities as per the budget – good to have account at specific project site

End of Presentation

Thank you

ANY QUESTION?

Enabling Community Forestry in Papua New Guinea. Project number: ACIAR FST/2016/153

Nursery Training at Atzunas community

By: Clifford Single
Date: 6th November, 2018

1. Introduction

The training was conducted at Atzunas Community on the 17th of October, 2018. Most part of the training was practical, few were on diagrams and verbal explanation. The training was design in a way that not too much time was to be spent in the community but at the same time enabling participation of most of the community members. There was a game at the end of the training and prices given out to make it interesting capturing. There were about 90 participants, 15 women and 75 men.

1.1. Brief explanation of the two seeds used in the training

The two tree species the community were trained on was *Eucalyptus pellita* (Pellita) and *Canarium indicum* (Galip). They were both preferred by the community as identified through the preferences studies conducted earlier. The Pellita will be used as shade tree for *Theobroma cacao* (Cocoa) later on in the project. Also this two species represent the two different types of seeds, those with hard coat (Galip) and those without hard coat with small seeds (Pellita). Training the community on the different techniques to nurture these two different types of seeds will give them a fair idea on what to do with other species with similar seeds. The actually activities of the training is discussed below.

2. What was done

2.1. Phase 1 – Separation of the community into 3 groups

The participants were told to separate into 3 groups and assign to each station (**Table 1**). The reason for 3 groups rather than less/more than 3 is because I believe there are 3 different target groups in the community: (1) Elderly men, (2) Young men and (3) Women (Young & Old). They were not told to separate into those specific groups but just to separate into three groups. They themselves choose which group they feel comfortable to join. The target is to make sure each participant is in a group he/she feels comfortable to fully participate. They were assigned to the first 3 station as shown in Table 1 below.

The table below shows what was explained and demonstrated in each station and the responsible instructor/s

Table 1: What was explained and demonstrated in each station and the responsible instructor/s

Station	Topics	What was explained and demonstrated	Instructor	Time (min)
1	Germplasm Collection and Preparation	a. Description of a good mother tree: - Tall and straight bole; - Free from pest and diseases; - Producing abundance seeds b. How to collect Pellita & Galip seeds: - From several mother trees and far from each other; - On branches that is alive and not dead c. How to prepare & store Pellita and Galip seeds: - Drying of Pellita seeds on top of a plastic bag under full sunlight and storing of seeds in a container; - Removing of the outer coat from Galip seeds, drying under full sunlight & storing to avoid been eaten by rats	Samson	5
2	Germination	a. Sterilization of germination medium for Pellita: - Separate sterilization of sand and soil; - Best process of sterilization; - Sieving of soil and sand with different sieve sizes b. Best germination medium mix: - 1.5 part soil : 1 part sand c. Sowing technique for Pellita and Galip: - Sub-irrigation method for Pellita; - Scarification method for Galip; - Amount of soils to cover the seeds after sowing; - Timing of watering; - Daily check and maintenance	Ora	5
3	Potting mix + transplanting to polybags	a. Best potting mix ratio (3 soil + 1 sand + 1 compost) b. Proper way for bagging soils in polybags: - Holes at bottom and sides of polybags if holes are not yet made; - Poking of the two bottom corners;	Simon	5

		- Filling to the brim; - Proper packing of soil to avoid large pockets or compaction; - Proper standing technique c. Application of water before any transplant (bed/tray + polybags) d. Using of a stick to make holes and the technique to follow if seedlings roots are too long		
4	Care and maintenance in Nursery	a. Watering b. Fertilizer application c. Hardening d. Grading e. Root pruning f. Pest and disease control g. Elevated hardening bed	Nathan + Lucas + Kanchana	5
5	Summery	Station 1 to 4	Clifford	5
	Nursery establishment	a. Best area to establish b. Basic nursery structures c. Local materials/tools that can be substitute if standard manufactured nursery materials/tools are not available		
Total min				25

2.2. Phase 2 – Rotation of the 3 groups to different stations

Each group rotated to another station after completion of a station and so on until they completed all 3 stations (**Table 2**). A summery was conducted in a chronological order after all stations were visited. After that, participants were given about 15-20minutes break while the team prepared materials for the game. Kanchana was given that time to conduct her research.

The table below shows the rotation cycle

Table 2: Rotation cycle of the different groups to each station

Station No.	Group No.
1	1
2	2
3	3
1st Rotate	
1	3
2	1
3	2
2nd Rotate	

18 Nursery training at Atzunas community

1	2
2	3
3	1
Combine	
4	1, 2 & 3
5	1, 2 & 3

2.2.1. Kanchana's research

Below was what Kanchana did with the help of Nathan.

Exercises for
Kanchana research.c

Images

Sketching of the visioning map by males (left) and females (right)

2.3. Phase 3 - Game

At first, before the actually training, the criteria (**Table 3**) and prices (T**able 4**) were explained so that in a way it help motivated them to be attentive in the training.

The game composed of 3 representatives from each group answering simple questions individually on different stations until they completed all first 3 stations (station 1-3). The game was to make the training interesting and capturing. It was also to prevent any future dispute that may arise regarding limited number of rewards been given out only to few selected participants. It was also to help us analyze whether they understand what has been taught. The table (**Table 3**) below are the questions asked.

Table 3: Criteria

Station No.	Questions	Points
1	How to identify a good mother trees?	5
	How to collect, prepare and store Pellita seeds?	5
Pellita		
2	Is it necessary to sterilized soil?	1
	What is the best germination mix?	3
	How to do a sub-irrigation method?	1
	How much soil to add after sowing?	1
	Frequency of watering	1
Galip		
3	What is the best germination mix?	3
	What is the best potting mix ration?	2
	How to bag soils in polybag?	3
	What is the best transplanting practice?	3
	How to arrange polybags on transplanting shed?	1

2.4. Phase 4 – Rewards

The rewards were given only to chosen individual because there were limited stocks available (**Table 4**). They were given out to one or two members of each clan present at the training as well as respected individual in the community and those taking part in the game with the help of two locals to identify the individuals in each clan. The individuals with the rewards were told to help supply Pellita seedlings to any interested person in their clan. Names of people receiving the rewards were recorded.

Table 4: Rewards

Items	Quantity
Germination tray	25
Germination shed plastic (Cut into suitable size to cover the germination tray)	25
Green shed (Cut into suitable size to cover the germination tray)	25
Polybags size	
›› Large (100x200x40mm)	About 20 (each person)
›› Small (75x150x40mm)	About 30 (each person)
Galip seeds	125 (5 in each large polybags)

Note: Each person received 1 germination tray, 1 germination shed plastic, 1 green shed, about 50 polybags and 5 Galip seeds.

3. Outcome

We received about 29 more people who were interested apart from the previous 15 interested people. The 29 requested for germination trays and green shed.

4. Challenges

Challenges	What was done to meet the challenges
Literacy	Most of the locals speak and understand the local vernacular so we brought in Lucas Nami from Marawasa (Local nursery officer) to help with the training
Limited availability of nursery material to be given out	With the help of the locals, materials were given to representatives of clans present at the training. The representatives were told to also help to supply some Pellita seedlings if their clan members are interested. They were also advise on other ways to improvised
Availability of other nursery materials for more practical	We cannot do more practical on some of the nursery practices so we had to explain clearly on those other practices before moving on

5. The next step

We still need to supply the other interested groups with germination tray, green shed and polybags. Also following up on the ones who already received the nursery materials. Nursery establishment is in progress with the interested family. Cocoa training will be after there is evidence of Pellita growing in the field.

6. Images

6.1. Introduction

Top: Nathan explaining the ACIAR projects in PNG and its purpose regarding this project to the community members. **Bottom:** Clifford explaining the training activities and the criteria

6.2. Stations

Top: Groups in station 1 & 2. **Bottom:** Groups in station 3

6.2.1. Station 1 - Germplasm Collection and Preparation

Samson explaining how to collect, prepare and store Galip and Pellita seeds to participants

6.2.2. Station 2 - Germination

Ora demonstrating how to prepare the germination tray for sowing Pellita seeds

18 Nursery training at Atzunas community

6.2.3. Station 3 - Potting mix and transplanting to polybags

Simon demonstrating the best potting mix ration and bagging of polybags

6.2.4. Station 4 - Care and maintenance in Nursery

Lucas and Nathan explaining how to do maintenance and care for the seedlings in nursery

6.2.5. Station 5 - Summery and Nursery establishment

Clifford explaining the different structures in establishing a new nursery and the local material to substitute if standard nursery materials are not available

6.3. Game

Clifford assessing one of the representatives of a group at station 1

Assessment of the Seedling Production System of RAIL Forest Nursery

Nestor Gregorio[1]

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Introduction

Climate change is a global challenge. To help curb its adverse effects, many countries have committed to restoring deforested and degraded forest landscapes through partnerships with the public and private sectors. Smallholder tree farming, agroforestry and large-scale forest restoration projects are commonly undertaken through the active planting of seedlings grown in forest nurseries. The nursery cultural practices influence the resulting quality of seedlings, which is imperative to promoting the success of tree growing and reforestation projects.

The Ramu Agri Industries Ltd. (RAIL) has established a forest nursery to satisfy the seedling requirement of the company's research and development projects. The nursery also caters for the seedling demand of communities and individuals interested in tree farming activities. A visit to the forest nursery of Ramu Agri Industries Ltd. (RAIL) was conducted to evaluate the nursery structure, seedling production practices and seedling quality. The assessment was undertaken as part of implementing the ACIAR-funded research project FST/2016/153 *Enabling Community Forestry in Papua New Guinea.*

Nursery set-up and construction

The nursery of RAIL is located inside the compound of the company at Ramu Valley. The nursery is semi-permanent, using concrete blocks and lumber for germination beds, steel bars as frames for germination and transplant sheds and nylon nets as shade material (Figure 2a). Elevated hardening beds made of steel are also used (Figure 2b). The nursery set-up generally followed the standards in producing high-quality seedlings. The water supply is permanent and distributed using hoses and sprinklers. There is a potting shed, which also serves as storage of potting medium with a roof that protects the medium from getting wet during rain events. The production capacity of the nursery is approximately 20,000 seedlings. A regular staff employed by RAIL manages the nursery.

Seedling species diversity

The nursery produces indigenous and exotic tree species, including *Eucalyptus pellita, Intsia bijuga, Pterocarpus indicus, Tristiropsis acutangula, Pinus sp., Azadirachta indica, Gnetum sp.* and *Aleurites moluccana*. The report of Zephaniah (2020) revealed increasing seedling species diversity from the inception of the nursery in 2004 up to the present. A significant increase started in 2014 due to collaboration with two ACIAR-funded research projects on forest and landscape restoration and community forestry. The diversity of species increased from six species in 2004 to 94 in 2020.

a b

Figure 2. The construction of germination and transplant shed (a) and elevated hardening bed (b) in RAIL nursery

Nursery management practices

A mixture of soil and sand is used as a germination medium. This combination was found appropriate based on trials made by the previous ACIAR Q-seedling Project in the Philippines and is widely used in the country. Black polybags are used mainly as seedling containers, although a few seedlings are grown in plug and Hiko trays (Figure 3). Plug trays and Hiko trays are excellent seedling containers because they have root trainers, which prevent root curling or pot bounding. Seedlings are sun-hardened on elevated hardening beds, which is ideal for producing high-quality seedlings. Seeds are mainly used rather than wildlings indicating that RAIL has considerable access to mother trees. Several studies showed that seeds promote high seedling survival and proper root system development.

Figure 3. Hiko trays and plug trays used in seedling production at RAIL nursery

Seedling quality

The physical quality of seedlings is generally good, with minimal signs and symptoms of pests and diseases. Some seedlings of *E. pellita* have damaged leaves caused by leaf-feeding insects; however, the degree of infestation is not significant. Seedlings in plug trays and Hiko trays developed desirable root forms, and those grown in polybags have not exhibited root systems growing outside the container. Sun-hardening is practised, although some seedlings appeared etiolated because of excessive watering.

Possible improvement

In general, the forest nursery of RAIL follows the ideal practice of high-quality seedling production. However, some aspects of nursery design and management practices can be improved to increase the efficiency and effectiveness of the forest nursery operation to produce high-quality seedlings. These improvements include the following:

Use polybags of appropriate size. Seedlings are grown in large polybags (Figure 4a). While large polybags will contain a high volume of potting medium suitable for seedling growth and development, this entails high production and transport costs. Large polybags with a high volume of potting medium will produce large seedlings, which are not ideal in most reforestation projects. Large polybags are appropriate for growing trees for urban forestry and landscaping but less suitable for forest restoration initiatives.

Some tree species produced in the RAIL nursery have large seeds. Sowing them in seedbeds rather than direct seeding to pots minimises using large polybags. Young seedlings can be potted in smaller pots. The 4 in. x 6 in. size polybag is primarily used in most reforestation programs (Figure 4b) in the tropics.

a b

Figure 4. Large polybag used in RAIL nursery and the 3in x 7in polybag commonly used in reforestation programs in the tropics

Timely potting of seedlings*.* Some seedlings are left growing in germination beds (Figure 5). Ideally, seedlings are potted once these have developed two pairs of leaves plus the cotyledon (if present). The sooner the seedlings are potted, the lesser the occurrence of seedling mortality. Also, potting mature seedlings will require large containers because of the extensive root system. Potting large seedlings in small containers will likely result in root deformities such as J-rooting.

Figure 5. Mature seedlings of *A. molucannus* and *P. indicus* left unpotted

Grading seedlings on hardening bed. Seedlings are not growing at the same rate; some seedlings are taller than others. Height grading in the nursery is a simple activity but profoundly affects the growth and morphological quality of seedlings. Grading facilitates the growth of short seedlings by allowing them to receive ample sunlight. Without grading, small seedlings will remain overtopped and culled when seedlings are taken from the nursery. It is necessary to grade the seedlings on hardening beds at RAIL nursery to achieve uniform seedling growth. This is done by arranging the seedlings according to height, usually about two months from potting or when they are subjected to sun-hardening.

Unnecessary use of steel screen as a seedling spacer. It is ideal to arrange seedlings on the nursery bed with substantial space to expose seedlings to sufficient sunlight. A steel screen on the hardening bed helps create space between seedlings (Figure 6a). However, it has the disadvantage of being expensive and reducing the volume of seedlings placed on the hardening bed. Instead of using this as a spacer, seedlings can be arranged in groups of five rows and leave a space of about 20 cm between groups (Figure 6b).

a b

Figure 6. Seedlings spaced with screen spacer at RAIL nursery (a) and suggested seedling arrangement in rows with space in between seedling groups (b)

Use of appropriate recovery chamber. Using a recovery chamber has helped enhance the recovery and improve the survival of newly potted seedlings, wildlings and cuttings. A recovery chamber is used in the RAIL nursery (Figure 7a). However, the design is inappropriate, which could be the reason for the considerable mortality of newly potted seedlings. The design of the chamber may protect seedlings from the wind, but it will not create the microenvironment necessary for the recovery and development of newly potted seedlings. There is a need to redesign the recovery chamber used in RAIL. An example of a simple and low-cost but effective recovery chamber is presented in Figure 7b.

Figure 7. The recovery chamber in RAIL (a) and the one used in a community nursery in the Philippines (b)

Improved nursery design. The RAIL nursery complies with the basic structure and set-up of a nursery to produce high-quality seedlings. However, the efficiency of operation can be enhanced with minor improvements. For example, transplant beds can also be used as hardening beds to remove the necessity of moving seedlings from transplant to hardening beds. This will minimise the nursery labour requirement and reduce the operation cost. This design will require the shade material on the transplant shed to be removable when seedlings are subjected to sun-hardening. Unlike the current practice where seedlings on transplant beds are placed on the ground, the suggested set-up will use elevated transplant beds because these will eventually become hardening beds.

Appropriate frequency of watering. Seedlings are hardened not only by providing total sun exposure but also by reducing moisture uptake to accustom them to field conditions. Regulating the watering frequency and placing seedlings on elevated hardening beds reduce moisture uptake. While hardened seedlings in RAIL nursery are placed on elevated beds, the frequency of watering and water volume are not regulated. The frequent watering defeats the use of an elevated hardening bed and results in lanky seedlings (Figure 8). Although the root systems did not absorb moisture from the soil, frequent watering provided abundant moisture and nutrients to the hardened seedlings resulting in their rapid increase in height. Lanky seedlings are unlikely to survive in the field when soil moisture is limited.

Figure 8. Etiolated or lanky seedlings of *E. pellita* placed on an elevated hardening bed

Potential to promote community forestry in Ramu Valley

The RAIL nursery can be crucial in promoting community forestry in Ramu Valley and neighbouring places. Aside from the provision of seedlings, the nursery may serve as an extension and training facility, providing technical support to managers of village or clan nurseries. It may also serve as a tree seed centre, distributing seeds of species that villagers have difficulty accessing germplasm. RAIL can document the location and track the phenology of mother trees for various species and develop a database of germplasm sources. RAIL can also undertake nursery and field trials to establish new silvicultural techniques to support the success of community forestry. A hedge garden of selected species with a limited germplasm supply can also be established in the nursery using a macro-somatic propagation technique.

ACIAR Project FST/2016/153 Enabling Community Forestry in Papua New Guinea

DS 402 F1 Mixed Species Trial Commencement Report

Compiled by: Nathan Wampe

20th March 20, 2019

1.0. Introduction

Forest Landscape Restoration (FLR) manifests through different processes such as, new tree plantings, managed natural regeneration, agroforestry, or improved land management to accommodate a mosaic of land uses, including agriculture, protected wildlife reserves, managed plantations, riverside plantings and more [1]. It is fundamental that suitable tree species and planting systems need to be identified in order to promote FLR. However the challenge is to identify which of these systems work well with the different tree species.

A prescribed activity of the ACIAR Project FST/2016/153 is to identify suitable tree species and establish effective planting systems in order to promote forest landscape restoration in Papua New Guinea. As a result a mixed species trial was established in Ramu Valley by project staff in Ramu Agri-Industries Ltd (RAIL) and visiting Research Fellow Nestor Gregorio from the University of Sunshine Coast, Australia.

2.0. Objective

The following are objectives of the trial

Main Objective:

- **Identify suitable tree species and their ability to grow together in a specific planting system**

Other Objectives:

- **Identify optimal fire management techniques for a planted block**
- **Identify the effectiveness of weed control measures that will result in minimal required labor for block maintenance**

3.0. Significance of the Experimental Results

The results can be utilised to promote optimal systems used for promoting Forest Landscape Restoration in Papua New Guinea

4.0. Research Methods and Materials

The details of the species selected, the planting site, and experimental design, activities associated with experiment establishment and continuous maintenance, monitoring and data collection are presented below.

4.1. Site Selection

The trial site is located in Usino Bundi District in Madang Province. The site is adjacent to D South 300, the name of the nearest sugarcane field. It is inside RAIL's declared Forest Rehabilitation site and about 7 km from RAIL industrial compound. The specific coordinates for the site is 6°00'07.7"S 145°52'56.0"E. *Imperata cylindrica* (Kunai grass) is the dominant cover. The land is generally flat and homogenous regarding aspect, surface configuration, and vegetation cover. The annual average rainfall of the site is 1950mm per year [2]. The location and initial appearance of the site are shown in Figures 1 and 2 respectively.

Figure 1. Location Map of Mixed Species Trial

Figure 2. Field Trial Site initial site inspection

4.2. Species Selection

Sixteen species are used for this trial. The selection was primarily based on the importance of the species for ecological, social, and economic purposes. The categories of species being legume or not was also considered in the selection process to allow investigation on the complementarity effect of legumes to non-legumes. Table 1 presents the list of the species and their reasons of being selected

Species No	Species Name	Reason for Selection
1	*Castanospermum australe*	Timber a good substitute for teak, seeds are edible; shade tree; windbreak; extensive root system is used to protect riverbanks and catchment areas
2	*Terminalia kaernbachii*	Edible fruit with high nutrition value,
3	*Pterocarpus indicus*	Premium timber quality for construction and furniture; the leaves used in traditional medicine
4	*Gnetum gnenom*	Edible leaves; hedgerow and intercropping species
5	*Trichospermum*	Strong vines utilized for house construction
6	*Melanolepsis multiglandulosa*	Bark skin utilized for snake bite treatment in Ramu Markham Valley; resistant to termites; firewood
7	*Octomeles sumatrana*	Young leaves are edible; dye is obtained from the bark; riverbank stabilization
8	*Adenanthera pavonina*	Edible seed very high protein content; young leaves as vegetable; ability to fix atmospheric nitrogen, shade for cocoa, coffee, rubber 9
9	*Tristeropsis*	Wood for house construction, resistant to termites
10	*Elaeocarpus sphaericus*	Wood for house construction
11	*Nauclea orientalis*	Yields a soft easily-cut wood. A commercial hardwood. In terms of agroforestry the tree is planted to control soil loss on riverine areas. A hardy, pioneer species with dryland reclamation potential, it is also an excellent shade tree. The leaf litter, as it decays replenishes soil fertility
12	*Bishchofia javanica*	Edible seed, obtained from the seed
13	*Canarium indicum*	Edible fruit and seed; the wood has some resistance to fungi and termites but susceptible to dry wood borers
14	*Aleurites moluccanus*	edible fruit, edible seed after boiling, The wood is moderately heavy; moderately hard; moderately strong; not very durable, having some resistance to fungi and termites but susceptible to dry wood borers
15	*Instia bijuga*	Premium wood quality
16	*Eucalyptus pellita*	Commonly utilized for house construction along Markham and Ramu valley, widely used for firewood and charcoal, an excellent shade tree and can also be used as a windbreaker.

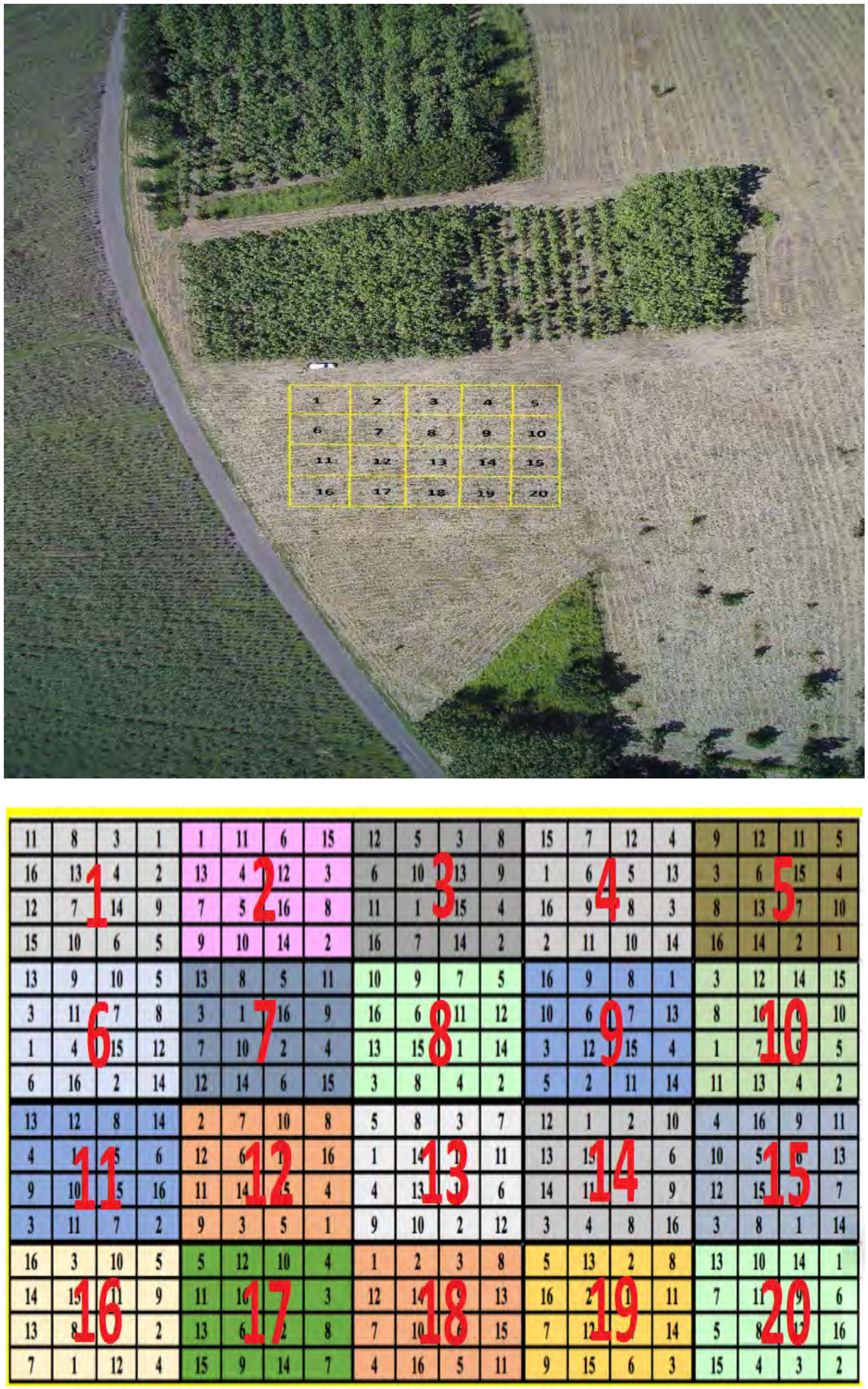
4.3. Research Design

The field trial is established according to the design developed by Lamb et al, (1998). A total of 16 tree species are used in this experimental trial. There are 20 plots, in each plots one seedling each of the 16 species were planted. Because there are 20 plots, each tree species will have 20 seedlings each to be planted. The 16 seedlings of different species will be distributed randomly in each plot. Randomisation was achieved by numbering 16 pieces of papers which were placed inside a paper box. Each number corresponds to a species listed in Table 1. The box was shaken, and a number was drawn one at a time. For Plot 1, the first number drawn correspond to Plant 1 in the plot. The second drawn number refer to Plant 2. The process was repeated until all 16 numbers were drawn. The same process was repeated in Plots 2 to 20. Figure 3 presents the species distribution in each plot.

Figure 3. Species Distribution in each plot

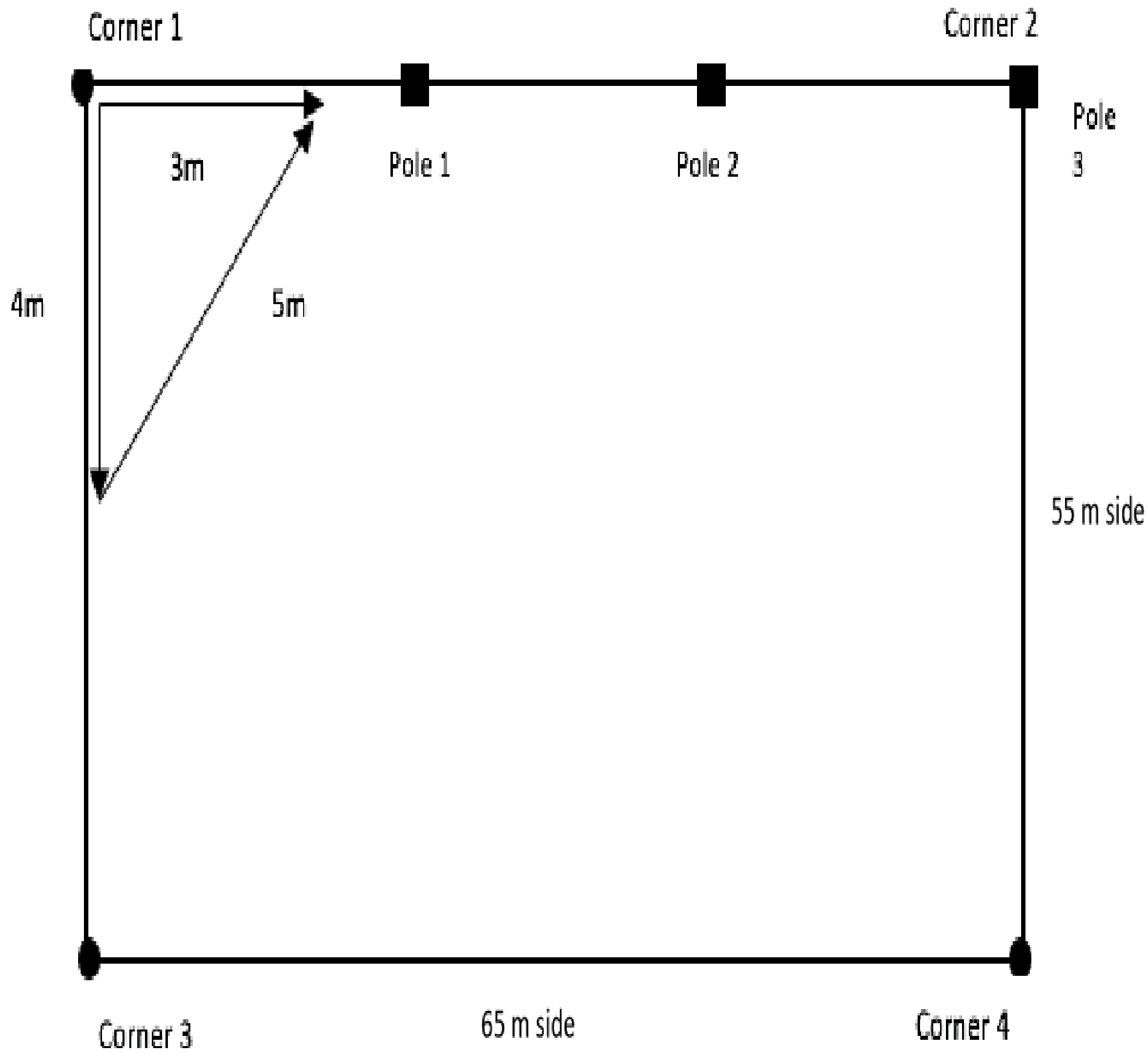
11	8	3	1	1	11	6	15	12	5	3	8	15	7	12	4	9	12	11	5
16	13	4	2	13	4	12	3	6	10	13	9	1	6	5	13	3	6	15	4
12	7	14	9	7	5	16	8	11	1	15	4	16	9	8	3	8	13	7	10
15	10	6	5	9	10	14	2	16	7	14	2	2	11	10	14	16	14	2	1
13	9	10	5	13	8	5	11	10	9	7	5	16	9	8	1	3	12	14	15
3	11	7	8	3	1	16	9	16	6	11	12	10	6	7	13	8	16	6	10
1	4	15	12	7	10	2	4	13	15	1	14	3	12	15	4	1	7	9	5
6	16	2	14	12	14	6	15	3	8	4	2	5	2	11	14	11	13	4	2
13	12	8	14	2	7	10	8	5	8	3	7	12	1	2	10	4	16	9	11
4	1	5	6	12	6	13	16	1	14	16	11	13	15	7	6	10	5	6	13
9	10	15	16	11	14	15	4	4	13	15	6	14	11	5	9	12	15	1	7
3	11	7	2	9	3	5	1	9	10	2	12	3	4	8	16	3	8	1	14
16	3	10	5	5	12	10	4	1	2	3	8	5	13	2	8	13	10	14	1
14	15	11	9	11	16	1	3	12	14	9	13	16	2	10	11	7	11	9	6
13	8	6	2	13	6	2	8	7	10	6	15	7	12	4	14	5	8	12	16
7	1	12	4	15	9	14	7	4	16	5	11	9	15	6	3	15	4	3	2

Figure 4 (a) and (b) Configuration of the twenty plots within the block



4.4. Establishing of Experiment block

A planting block with a dimension of 65 m by 55 m was established (Figure 3). The four corners of the experimental block was established using two 100-m tapes. One corner was established, and a tape was laid up to the 65m mark. A second tape was laid to measure a 55 m distance corresponding to the adjacent side of the rectangular block. The team applied the '3-4-5 method' to ensure that two adjacent sides are perpendicular to each other (Figure 5). To establish a straight line, the '3-pole method' was adopted.



4.5. Site Preparation

After the block was established, tall *Imperata cylindrica* (Kunai grass) present in the block were slashed using a slasher. This was done in order to effectively establish the planting layout. The cut biomass were left in the block for mulching purposes. This was done 5 days before establishing the planting layout.

Figure 6 (a) Slashing of tall Kunai grass (b). Residual slashed Kunai grass left for mulching purposes

4.6. Establishment of planting layout

The site was slashed again using the slasher in preparation for establishing the planting lay out. The Kunai grass and other weeds present were removed to ensure that the area is uniform to reduce experimental error.

Planting points were established using a long rope, pegs, flagging tapes and a hundred meter surveyor tape. Each planting spot were marked with a peg (stick) longer than the grass inside the plots for easy identification. The sticks used as pegs were cut from branches of nearby trees.

The marking of the planting spots eventuated after the four sides of the block have been established (65m x55m). Using the 100m surveyor tape the vertical sides of the block (65m sides) were marked at 3m intervals each. All the 3m intervals were marked with a peg.

The surveyor tape was used to mark the long rope at 3m intervals and a flagging tape was tied around the rope to mark each interval.

The long rope was then pulled by two people, one on each end, at one point of the marked peg to the opposite marked peg. 4 people were in the block and pegged the planting spots as indicated by the flagging tapes tied on the ropes. This was done until 320 planting spots were marked within the block. This method saved occurred quite fast and as a result the planting layout was established quite rapidly.

4.7. Planting site preparation

The planting holes were prepared on the same day as the planting time. This was done right after the planting spots were marked. Approximately 15 cm x 15cm x 15 cm holes was dug which is suitable for the size of the seedling container (6 cm x 15 cm). It is ideal that planting holes will be large enough to accommodate the root systems plus ample room for the root systems to develop rapidly. A meter ruler was used to cross check the dimensions of the holes dug. A total of 320 holes were dug.

4.8. Planting

Planting eventuated on November 14, 2018, this was within the rainy season. Planting was completed in one day because of the availability of labor and the effectiveness of the methodology used in the planting layout establishment (the use of the rope to mark the planting spots).

The seedlings were transported from RAIL Nursery to the planting site and placed under nearby *Tectona grandis* trees which provided adequate shade.

There were 3 groups which consisted of four members each. One person cross-checked the trial design, the other loaded the seedlings from the seedling stacks to the wheelbarrow, the other hauled the seedlings in a wheelbarrow to the planting spots and the fourth one did the planting. Each seedling was carefully removed from the polybag, avoiding damage to the root system and placed into the hole. The soil was then pressed with the hands to avoid any significant gap between the soil and the roots because the roots absorb moisture and nutrients through direct contact with the soil.

The planting occurred with respect to the plot numbers in Figure 3, meaning the planting started in plot 1 and ended in plot 20. In each plot, planting occurred as per the design of each specific plot.

4.9. Maintenance of Trial

The invasive species *Imperata cylindrica* and *Megathyrsus sp* are common on site. Thus, manual and mechanical maintenance are needed. Three weeks after planting manual ring weeding was done at the base of each seedling to diameter of 1m. The frequency of the manual weeding will depend on the assessment of growth of the weeds.

Figure 7.(a) Ring-weeding at the base of seedling. (b) Breaking the soil to allow better aeration at the base of the seedling

Breaking of the soil at the base accompanied ring-weeding. This was to allow low soil compaction at the base of each seedling in order for the soil to have better aeration and allow oxygen to reach the roots of the seedling. This will enable the seedling to develop a healthy root system.

Mechanical maintenance is the slashing of tall Kunai grass within the plots and the boundaries of the block using a slasher. The 3m x 3m spacing between the seedlings is adequate space for the slasher to move in between the seedlings. The slasher has since done two pass slashing. This is a technique which involves slashing in each row (horizontally) and then slashing in each column (vertically).

In both ring-weeding and slashing the cut biomass are used for mulching at the base of each seedling. They are placed approximately 20cm away from the base of the seedling. This methodology has associated threats as well. It may allow fungi to breed that may affect the seedling and provide fuel for fire which enters the block. Therefore, soil has to be placed on top of the mulch after placing around the seedling.

Boundary slashing is done by the slasher to control weed from outside to enter the block and to allow for site accessibility for trial monitoring and data collection..

The use of chemical to remove weed and fertilizer application are considered, however a Standard Operating Procedure (SOP) needs to be formulated before both activities are conducted for safety purposes.

Regular monitoring to prevent damage from passersby, fire threats, ruminants and vandals are conducted. Monitoring is also essential for the early detection of pest and disease occurrence.

Figure 8. Seedlings growing in different plots after slashing (March 2019)

4.10. Fire Management

Initially a 1m buffer was marked out from each side of a block. This was used as a reference where a 5m strip was marked on each side of the block and ploughed. The ploughed 5m strip is marked at an interval of 1m where a legume cover crop, *Mucuna bracteata* is planted. This is will prevent outside fires entering the block. The same legume cover crop will be planted in each of the 20 plots between each seedling (1.5m). This is to minimize the risk of fires spreading within the block. The cover crop will encourage soil nutrient accumulation for the benefit of the seedlings and also act as a weed control measure.

Figure 9. Initial marking of the 5m Strip

Figure 10. 5m strip established after a 1m buffer from the block

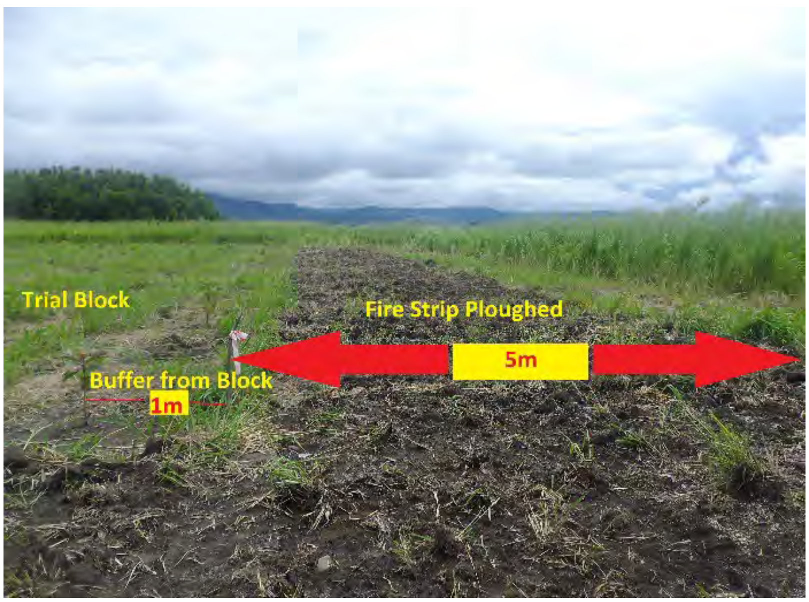


Figure 11. ***Mucuana brateata*** **growing in the 5m fire break**

4.11. Trial Measurements

The parameters of measurements are base diameter, height, seedling mortality and general health. Base diameter was measured using a digital caliper and height using a meter stick. Seedling mortality and general health were based on seedling observation. Initial measurements commenced a week after panting and will continue on a monthly basis for 4 years. Diameter at breast height (DBH) will be recorded when the tree height reaches 3 meters and measured using a diameter tape. A calibrated pole will be used once seedlings are beyond 3 meters tall.

Figure 12. (a) Using a digital caliper to measure the base diameter (b) Using a meter stick to measure the height of a seedling

4.12. Data Organization and Analysis

4.12.1. Data Collection

A field sheet is used during data collection and stored in a specified folder. The field sheet shows the tables for data entry, a sketch map of the trial site, the design of the block and the sketch of the data collection protocol.

4.12.2. Data Collection Protocol

A sketch of the data collection protocol with respect to the block and plot configuration has enabled data collectors to follow the same protocol when taking measurements on specific seedlings in the trial. See attached in Appendix 1 the sketch data collection protocol, the plot numbers indicates the order of data collection. In each plot the seedlings are assigned numbers also indicating which specific seedlings will be measured first as seen on Appendix 2.

4.12.3. Data organization and analysis

Data gathered have been encoded into a database in Microsoft Excel. This process will continue for the length of the measurements duration.

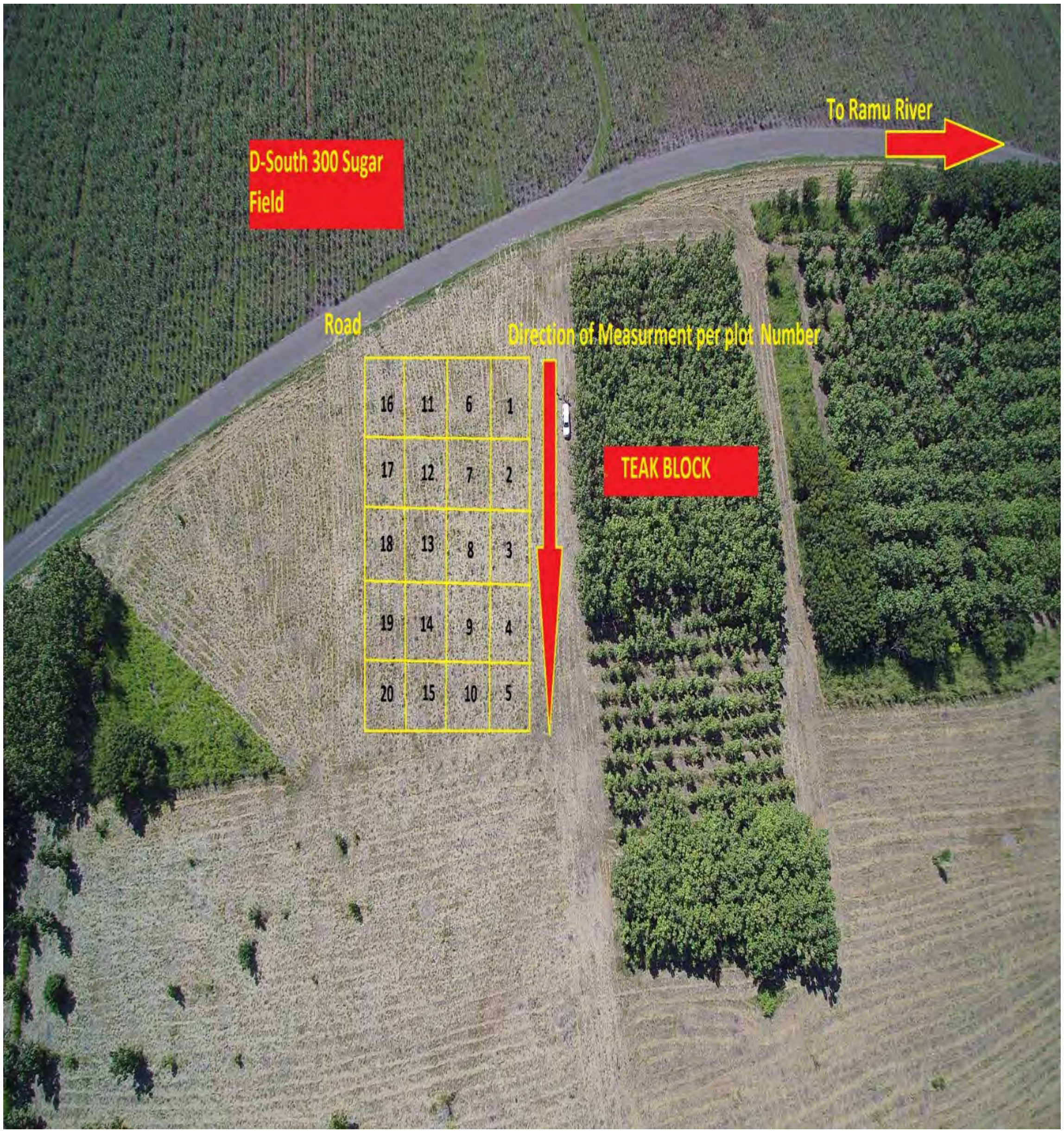
References

[1] International Union for Conservation of Nature 2019. *Forests, Forest Landscape Restoration*. Viewed 20th March 2019, https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration

[2] Remote sensing applications for peanuts in Australia and Papua New Guinea - Scientific Figure on ResearchGate. Viewed 20th March 2019, https://www.researchgate.net/figure/Average-rainfall-observed-in-the-Markham-Valley_tbl23_303331422

Appendices

Appendix 1. Measurement Protocol as per the 20 plots



Appendix 2. Measurement protocol of the 16 species in each plot.

4	8	12	16
3	7	11	15
2	6	10	14
1	5	9	13

COMMENCEMENT REPORT

Expt Reference: FST/2016/153 – Field Trial 1, Goroka, PNG

Field Files: Phase 1: Expt No 1. (Establishment date: 18/09/2019
Phase 2: Expt No (date to be established.)

Title: Mixed Species Trial 1

Subtitle for phase 1:
Subtitle for phase 2:

Preamble:

The selection tree species and design of planting systems in promoting large-scale community-based forestry programs in Papua New Guinea is crucial in order to demonstrate to interested tree farmers and communities. However, there is a dearth of information regarding the growth of many tree species that are potential for reforestation programs and smallholder tree farming projects in the country. While there are publications outlining likely site requirements, growth estimates and suggested silvicultural systems for both exotic and indigenous species for tropical countries, these are seldom based on evidence of actual growth from rigorous field trials. For most tree species, there is a lack of data on species performance on different sites and under a range of site conditions. There is very limited information on mixed-species plantings, especially about complementarity or antagonistic relationships when planted together. There is also little information on optimal planting density and planting configurations that promote early site capture and maximum growth of trees.

Research questions:

This study aims to answer the following research questions:

1. What tree species demonstrate high potential suitability for community forestry in Goroka and other areas in Papua New Guinea?
2. What is the optimal spacing for the early site capture of key forestry species?
3. At what spacing the key species should be planted to promote the development of good stem form for sawlog production?
4. What is the optimal period to apply thinning and pruning treatments to facilitate the production of trees with good stem form for maximum timber recovery?
5. Do species combinations provide improved performance, greater competition or no interactions i.e. what species should be planted together and what species combinations should be avoided?

Experiment design

A. Mixed species trial 1 – Matox,

A mixed species trial was established to identify which species combinations provide improved performance, greater competition or no interactions i.e. what species should be planted together and what species combinations should be avoided. The same species used in the variable spacing trial were used in the mixed planting trial. The experimental design followed FRI *(Anton Lata)* which allows for the testing species interactions of four species at a range of different mixture ratios using a compact field layout of 40 m x 40m plot with 4 replicates. Seedlings were planted at the spacing of 3 x 3 m. This mixed species planting trial will provide valuable information about the interactions of the four species when grown in varying mixture ratios.

Future management of phase 1:

During establishment phase initial field measurements was carried out at out planting and to continue every three months thereafter for the first year. Measurements will then be done at six months until year five and then once a year afterward. Seedling mortality, height, base diameter, photosynthetic rate and general health were recorded. Other parameters including light intensity, and soil and air temperature and humidity will also be measured in same trial plots. Diameter at breast height will be recorded as soon as the trees reach 3 meters. Seedling height was measured using a 30cm rule while seedling base diameter was determined using a digital caliper.

Ring weeding is to be undertaken every quarter until year three. Regular tending to reduce the risk of grassland fire is carried out every six months or whenever necessary *(suggest every 3 months due to fast growth of weeds in the plot)*

Method and Materials:

Establishing the field trials involves a series of activities including a reconnaissance survey, establishing formal arrangements and legal agreements with the owners of the land where the trials will be established, meetings with clan (whenever applicable) to inform them about the trial, field planting, placing of signboards to advertise the trials, and possibly employing a local resident to oversee the experiments.

The experimental designs were adopted from *FRI (Anton Lata).* The boundary of plot (40m x 40m) size was surveyed using Suunto Compass and permanent corner pegs inserted with colored ribbons for ease in distinguishing the 4 corners. Experimental layouts were established using surveyor’s tape and calibrated ropes. The 3-4-5 method of establishing plot corners was applied and straightness of planting lines was determined using a compass. Pegs were used to mark the planting spots and marked with colored ribbons corresponding to the four species that were used in the trials.

Planting holes were established on each planting point and seedlings of corresponding species were planted by inserting each seedling in the planting hole and root systems covered with soil up to the root collar level. Seedlings were watered after planting. Watering continued every day for a period of two months because of nearing end of dry season during field trial establishment. Fence was established around the experimental plots to protect the seedlings from potential damage by grazing ruminants and pigs.

Materials & Equipment’s Used
- 1 x Suunto Compass
- 1 x 50m tape
- Colored ribbons
- Fencing Materials
- Seedlings - 4 x species listed below

21 Commencement Report – Mixed Species - Goroka

- Digital Caliper – Initial Measurement of Seedlings

Location: Matox, Lufa District, Goroka. EHP
(see location map attached).
Grid reference: UTM
Latitude & Longitude
South 06^{0} $15^{!}$ 33!!
Easting 145^{0} $25^{!}$ $40.7^{!!}$

Soil Type:

O & A Layer (Organic/Top soil) Black silty loam
B Layer (Subsoil) – Clayish
Overall description: Clay Loam - Black

Aspect/Slope:

South East @ 45%

South East @ 5% slope

Altitude

1437 m (als)

Rainfall:

Mean annual rainfall
Average rainfall @ 1,840 mm/year

Site Preparation:

Clear brushing of thick imperata grassland & burn

- *The site clear brushing of thick grassland & burning for planting*

Planting:

Dig holes within center of pegs @ a depth of 20 cm and plant

- *PNGFA Goroka staff with assistance of locals planting Matox Species trial 1*

Weed Control:

Hand weeding

Chemical application

Fertilizer:

Fertilizer compound (13, 12, 20) to be applied once 3 months after planting and 6 months thereafter.

Amount, concentration and application of 150grams per tree (3months after planting)

Fencing: Pig Wire with wooden Pegs

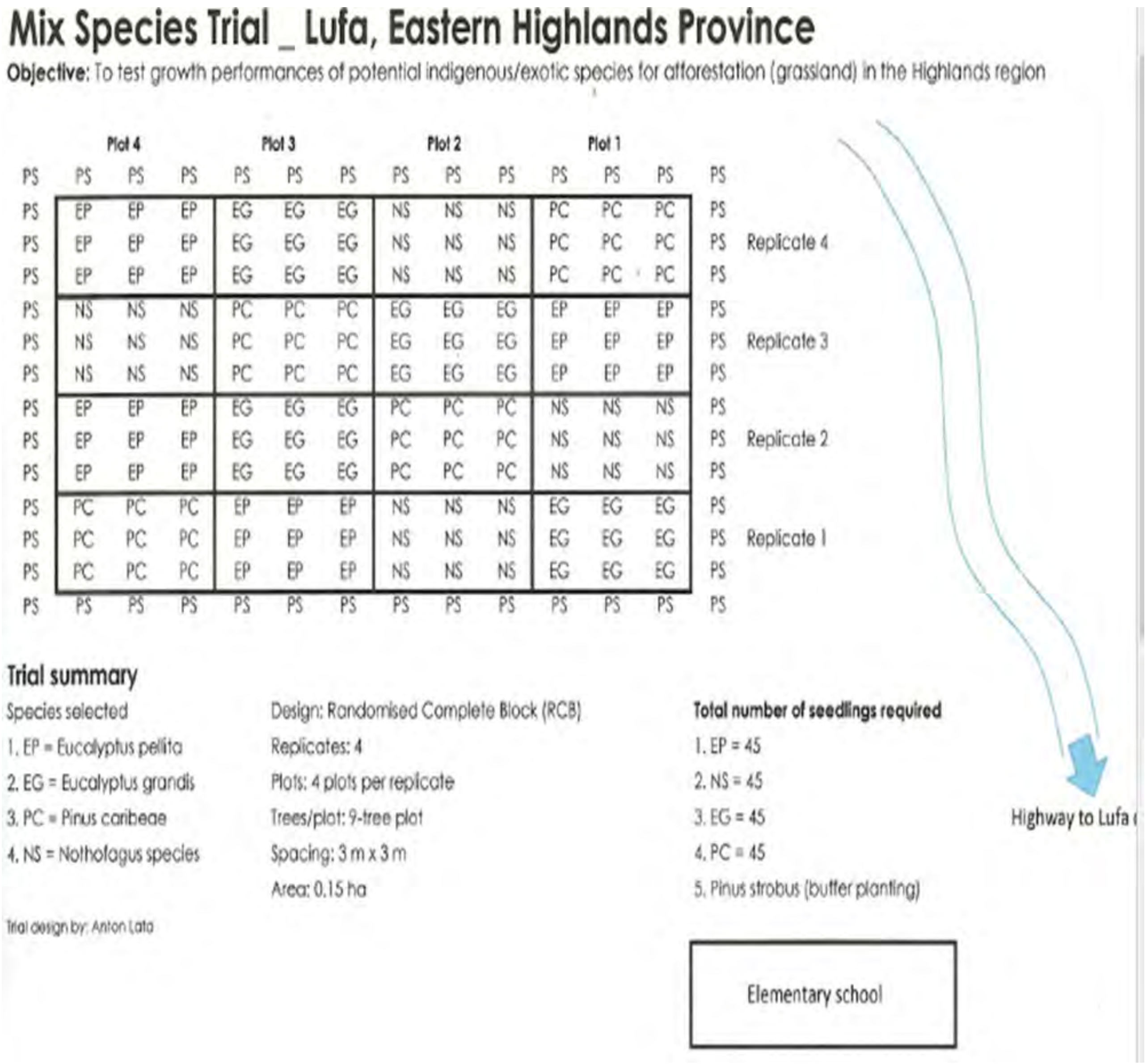
- *Photo view of Fencing done using pig wire & Wooden posts by local labour*

Species Details

For Matox trial 1- Four (4) species of economic and social importance were selected to be tested for this site. The following list species below,

Nothofagus grandis
Eucalyptus pelita
Pinus carribea
Eucalyptus grandis

Trial Layout Plan:



Mix Species Trial _ Lufa, Eastern Highlands Province

Objective: To test growth performances of potential indigenous/exotic species for afforestation (grassland) in the Highlands region

	Plot 4			Plot 3			Plot 2			Plot 1				
PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	
PS	EP	EP	EP	EG	EG	EG	NS	NS	NS	PC	PC	PC	PS	
PS	EP	EP	EP	EG	EG	EG	NS	NS	NS	PC	PC	PC	PS	Replicate 4
PS	EP	EP	EP	EG	EG	EG	NS	NS	NS	PC	PC	PC	PS	
PS	NS	NS	NS	PC	PC	PC	EG	EG	EG	EP	EP	EP	PS	
PS	NS	NS	NS	PC	PC	PC	EG	EG	EG	EP	EP	EP	PS	Replicate 3
PS	NS	NS	NS	PC	PC	PC	EG	EG	EG	EP	EP	EP	PS	
PS	EP	EP	EP	EG	EG	EG	PC	PC	PC	NS	NS	NS	PS	
PS	EP	EP	EP	EG	EG	EG	PC	PC	PC	NS	NS	NS	PS	Replicate 2
PS	EP	EP	EP	EG	EG	EG	PC	PC	PC	NS	NS	NS	PS	
PS	PC	PC	PC	EP	EP	EP	NS	NS	NS	EG	EG	EG	PS	
PS	PC	PC	PC	EP	EP	EP	NS	NS	NS	EG	EG	EG	PS	Replicate 1
PS	PC	PC	PC	EP	EP	EP	NS	NS	NS	EG	EG	EG	PS	
PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS	

Trial summary

Species selected
1. EP = Eucalyptus pellita
2. EG = Eucalyptus grandis
3. PC = Pinus caribeae
4. NS = Nothofagus species

Design: Randomised Complete Block (RCB)
Replicates: 4
Plots: 4 plots per replicate
Trees/plot: 9-tree plot
Spacing: 3 m x 3 m
Area: 0.15 ha

Total number of seedlings required
1. EP = 45
2. NS = 45
3. EG = 45
4. PC = 45
5. Pinus strobus (buffer planting)

Highway to Lufa

Elementary school

Trial design by: Anton Lata

Prepared by: Warea Andasua

Date: 23/09/2019

Maintenance and 3 Months assessment of Situm Variable Spacing Trial
Report No. 1
9th March 2020

Compiled by Haydrian Morte

1. SUMMARY

The days' activity were set out when the team of six officers put out plans according to the trial work schedule to refill mortality seedlings, tree assessment and tendering of the variable spacing trial at Situm. The group under the leadership of Haydrian Morte (ACIAR project Officer), consist Emen Johnson (ACIAR field assistant), Kalyo Depa (FRI field assistant), Panao Kiap (FRI field assistant) and John Langun (FRI driver).

2. INTRODUCTION

After three months of establishment, the Situm variable spacing trial is to be maintained and assessed according to the work plan scheduled for year 2020. The content of this paper is a brief report of the first 2020 maintenance activity which includes; refilled activity, tree assessment and tendering of the variable spacing trial that was carried out at Situm from the 2nd to the 4th of March 2020. The activity was conducted by four (4) to six (6) Officers at 9am from the time of travel and completed at 2pm/3pm when the Officers travel back to Lae.

3. ACTIVITY

3.1. Day 1 (02 March 2020)

The first day of the trip was a general visit to the trial after the long Christmas break and three months after establishment. A team of three officers and the driver was set out to the field to assess the status of the trial to plan out the activity for the next two days. Measurements of the heights were taken indicating the number of mortality. The total number of mortality for each species is shown in Table 1. It was also found that the trial was all covered under agricultural crops planted by the local communities.

Table 1: Total Mortality for each Species

Species	Mortality
Pometia form pinnata	4
Elaeocarpus angustifolius	13
Canarium indicum	8
Homalium foetidum	4

3.2. Day 2 (03 March 2020)

After planning out the other two days activities, day two activity was the measuring of tree diameter and refilling of mortality seedlings. Seedlings were transported from the FRI nursery to supplement those that were on site for mortality refill. Since the trial was covered with agricultural crops there was no need for intense tendering, thus little clearing around the trial was done.

3.3. Day 3 (04 March 2020)

This is the last day of the trip were all the work of data collection was completed. A team of three officers went back to the trial to complete collecting diameter of the trees and height of replaced trees.

4. DISCUSSION

4.1. Mortality

Taking into account the report of this trip, it was found that the mortality of almost all species have increased from the last assessment that was done two weeks after planting (figure 1). There were also gardening activities within the trial which may have caused the increased of mortality from the last assessment. Other reasons for increased mortality may include the climate of long dry weather condition and little rainfall for the last 3 months. All in all survival rates of *Pometia pinnata*, *Homalium foetidum* and *Canarium indicum* are more than 90% and about 86% survival for *Elaeocarpus angustifolius*. This shows that mortality for each species remain minimal at 3 months of measurement.

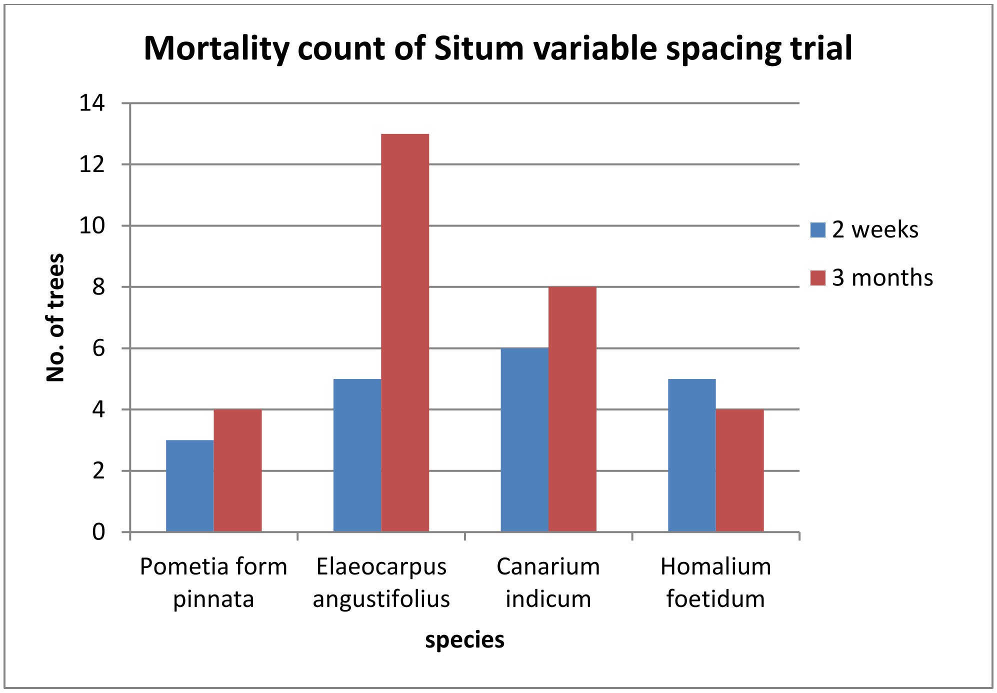


Figure 1: **Mortality of each species for week 2 and 3 months after planting**

Since gardening was already a part of the local benefits from the trial established, the team made sure that the same crops are planted trough out the trial so that uniformity is maintained to minimize more bias data during the assessment of the trial.

4.2. Change in growth

From the data collected it was also found that growth performances of all species have increased over the first 3 months. Figure 2 shows that there was an average diameter increase of 3.5mm after three months from the initial measurement at planting time. This shows that despite the gardening activities, growth performance was above average and this can also be concluded that agricultural crops have somewhat provided shade and other benefits to the tree seedlings for increase growth performance.

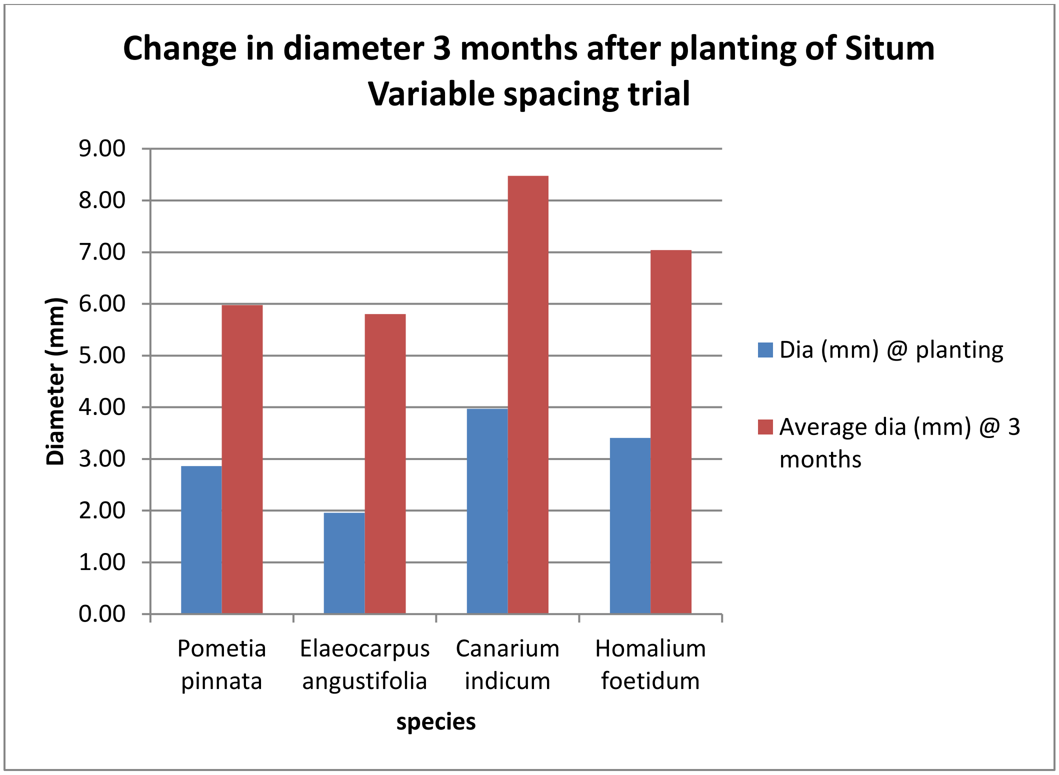


Figure 2: growth performance of the variable spacing trial, 3 months after planting

Taking into account all that have been discussed, it is concluded that mortality of the Situm variable spacing trial was kept at minimum rate and that there was an increase in growth from the time of planting till now. According to the work plan, this trip was also the last activity for mortality refill for the trial which means that any trees which died from now onwards will not be refilled and will be recorded as 'dead tree'. We are therefore looking forward for the near future result which will be taken from the 6 month measurement for the trial.

22 Commencement Report – Variable Spacing Trial Setun

23 Maintenance and 4 Months Assessment of Situm Variable Spacing Trial

Brief Summary and preliminary Results of the Species Trials

ACIAR FST 2016/157

PNG research Institute

Haydrian Morte

07th July 2021

Summary

The variable spacing trial was established to complete objectives from the previous phase of the project ACIAR FST 2011/057. The trial was established from seeds, seedlings and wildings propagated in the FRI nursery. Sources of this seedlings were from the West New Britain province and the Morobe province of PNG. According to the design by Vanclay, there were four species which are; *Pometia pinnata, Elaeocarpus angustifolius, Canarium indicum* and *Homalium foetidum* planted.

Another activity that was supposed to be completed is the establishment of the 20 species mixed species trial. To this date only one trip has been done in the purpose of this activity. The table below shows the detail activities and the dates of which these activities were carried out.

No of Trips	Activity	Targeted Date of Completion	Achievements/Comments
1	Clearing of site for the variable spacing trial at Muya 25 km from Lae towards Nazap	29th – 31st July 2019	Community involvement, demarcation of site and motivation to reforestation. Work at Muya was terminated due to project overlapping with another government project (The Wapi Golpu pipeline)
2	Demarcation of new site at Situm for the variable spacing trial	23rd September 2019	Area secured with verbal agreement between PNGFRI and the Land owner
3	Felling of Trees and stump removal of the site at Situm	9th – 11th October 2019	Involving local communities for FLR. Completion of tree felling and clearing of site
3	Inspection of local community work in progress in clearing and burning of debris	21st October 2019	Site Brushed, cleared and burn to the ground leaving remaining Tree stumps outstanding. Community engagement and beneficiary through labour compensation
4	Removal of remaining stumps to ground level, laying out of the trial,	5th – 8th & 11th November 2019	Site cleared, trial layout, picketing and planting completed

	Transportation of seedlings, picketing and planting		Activities were completed just before the mid-term review
5	Measurement of the variable spacing trial in 0 month	15th November 2019	Due to time and the wet weather condition the team return to the site 3 days later for initial measurement. Data collection and summary - Initial measurement of the trial was recorded
6	4 weeks Mortality assessment and refill	12th December 2019	All assessment and refill completed
7	3 months mortality assessment and final refill	2nd – 4th March 2020	Mortality assessment and final refill completed 3 months data collected. This was the last trip before PNGFRI closed office from the 27th of March to May 2020 due to COVID – 19 Pandemic
8	Inspection of trial for future activity planning and land negotiation for the mixed species trial	7th July 2020	Verbal agreement with land owner at Situm and Tikeleng. A follow-up meeting will be held at the end of July to finalise site selection for the mix species
9	9 Month Measurement and maintenance	04th Sept 2020	Tendering and pruning of double shoots stems and measurement of 9 month mortality, diameter and height of the trial
10	17 month Measurement	15th April 2021	Completion of mortality assessment, height and dbh measurement

Preliminary results

- Mortality

Mortality recorded during the four measurements are presented on the graph below. According to the schedule, mortality at 1 month and 3 month were refilled. This is why mortality dropped at 9 month and then starts to increase at 17 month. The graph shows that *Elaeocarpus angstifolius* has the most mortality (13) than the other three species. On overall the mortality rate for the trial is low.

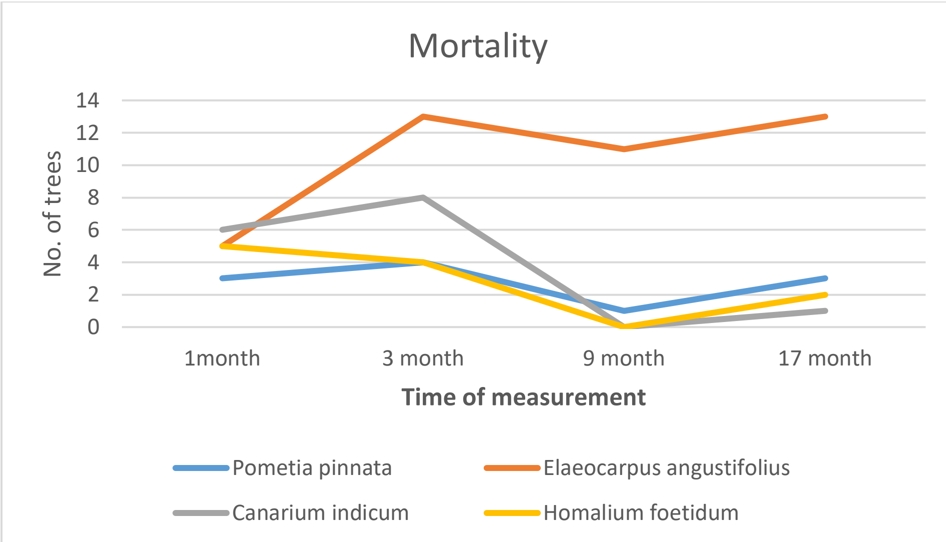


Figure 1: Preliminary result of Mortality

The two graph bellow shows the diameter and height of the four species at 17 month. Since there is a wide range of spacing (55 different spacing), they were group into 11 categories of 5 spacing each.

Although *Elaeocarpus angustifolius* diameter increases with wider spacing, *Canarium diameter* (and height) on the other hand decreases with wider spacing. *Homalium foetidum* and *Pometia pinatta* does not show a strong correlation with spacing at this stage.

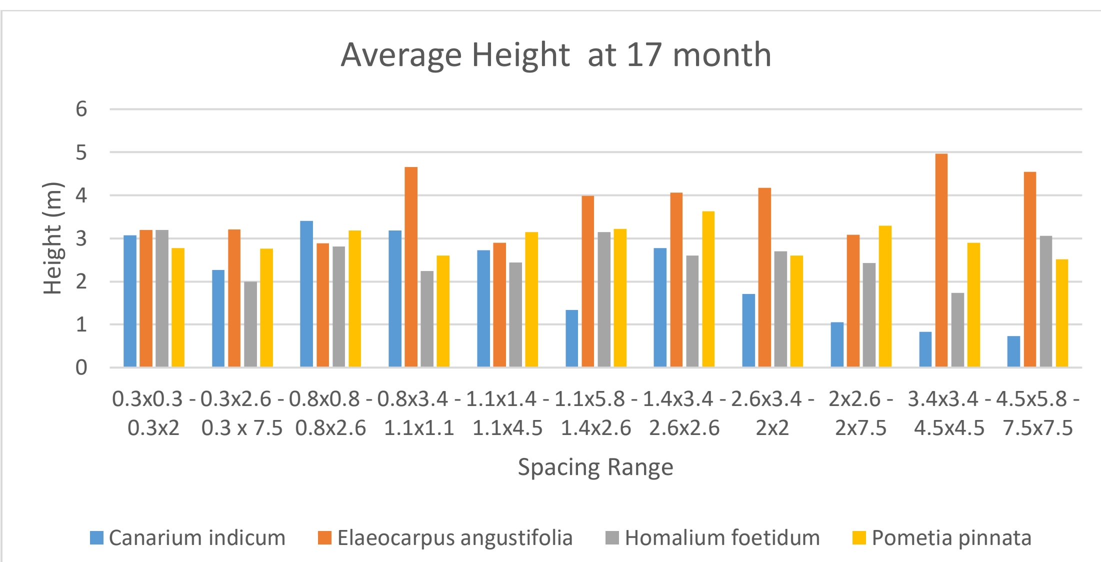


Figure 2: Preliminary result of Average Height

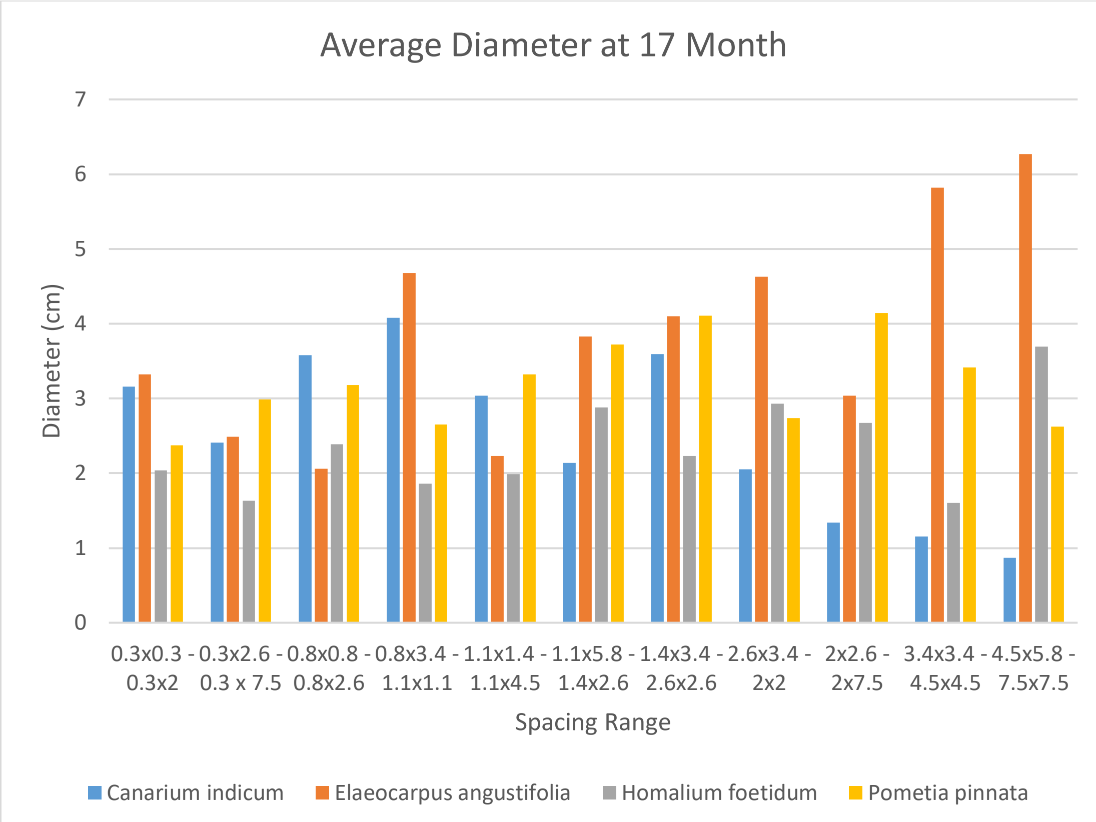


Figure 3: Preliminary result of Average Diameter

Limitations

The initial schedule for the trial was proposed to be measured at 3 month and 6 month on the first year and annually after the first year measurement. As reported we were not able to get the 6 month measurement due to the restriction of field travels caused by the COVID-19 pandemic. The team decided therefore to get 9 month measurement to compensate for the data missed at 6 month. In November 2020, the annual measurement of the trial was supposed to be carried out. This did not eventuate due to changes with the senior management in FRI which hindered the progress of the activities. The trial was therefore re-measured again at 17 month when the issue was sorted out.

Analysis of the data for the variable spacing trial has been very challenging as the design is not a standard design and has no replicates on spacing that was used. There was a 10 days' workshop with Professor Ashley Sparrow that was carried out via zoom on R-statistic however more understanding and training is still required to understand the software and be able to interpret the results obtained.

Way forward

With plans put forward for the establishment of the new species trial, the team is only waiting for the finance team to sort out acquittals and invoice so that activities of this trial can commence.

23 Maintenance and 4 Months Assessment of Situm Variable Spacing Trial

The team is looking forward for the Field Trial Training and Analysis to be able to better analyze the variable spacing trial data so that growth performance of the species over time can be presented clearly. This includes better presentation of the competition between species and spacing against diameter/height.

COMMENCEMENT REPORT

25th July 2022

Title: Mix-Species Trial - Tikeleng
Subtitle: Tikeleng square mixed-species trial
Compiled by: Haydrian Morte
Commencement Report-2022 13th April 2022
Haydrian Morte, June Mandawali, Wake Yelu, Gedisa Jeffery, and Anton Lata

Introduction

The mixed-species trial is a series of species trials implemented by ACIAR in the Philippines and within Papua New Guinea (PNG). This trial was one of the activities undertaken by PNG Forest Research Institute (FRI) during the initial phase of the project. The mixed-species trial is an additional trial to the variable spacing trial that was established in Situm, Morobe Province. The same species used in the variable spacing trial at Situm was used in the mixed-species trial at Tikeleng.

After a few Hi-cups and changes within the PNG Forest Authority (PNGFA) management, the FRI team put out work plans to accomplish incomplete activities. The aim was to establish the mixed-species trial in three sites within the Morobe province. It came at the time of the extension of the project period from September 2021 to September 2022. Work commenced in early January and the mixed-species trial was established in April 2022.

Although publications have outlined likely site requirements, growth estimation, and suggested silvicultural systems for both exotic and indigenous species for tropical countries, these are seldom based on evidence of actual growth from rigorous field trials. There is still a lack of data for most tree species on species performance on different sites and under a range of site conditions. There is also very limited information on mixed-species plantings, especially about complementarity or antagonistic relationships when planted together. The aim of this trial, therefore, is to identify which species combinations provide improved performance, greater competition, or no interactions i.e. what species should be planted together and what species combinations should be avoided.

Research Question

Do species combinations provide improved performance, greater competition, or no interactions i.e. what species should be planted together and what species combinations should be avoided?

Experiment Design

The experimental design follows Vanclay (2006) which allows for the testing of species interactions of four species at a range of different mixture ratios using a compact field layout of 60 m x 60 m plots. The experimental layout of the mixed species trial is shown in Figure 2. The symbols correspond to the four species that will be planted at the spacing of 3 x 3 m. This mixed species planting trial will provide valuable information about the interactions of the four species when grown in varying mixture ratios.

Method and Materials

Negotiation for the site was carried out in September 2021 when the FRI team took a 7-day camp out with the local land owner to assess the availability of wildings in their forest. The site was then selected and agreed on by the primary land owner. This site was a secondary growth from logged over forested vegetation. The team comprising FRI researchers and the local communities demarcated the area. After marking out a total area of 70 x 70 m, the area was cleared by local villagers, and woody trees were cut and stumps removed to ground level by the research team. The remaining debris and stumps were then burned and the 60 x 60 m area was mapped and marked in the field using the length tape, ropes, wooded pegs, and flagging tapes. After the plot and sub-plots were pegged out, planting holes were dug for each seedling prior to planting.

Future Management

Measurements

Measurements of height, DBH, mortality, general performance, and health will be carried out on all seedlings every three (3) months from the initial planting date for the first year and annually afterward.

Maintenance

The whole site is maintained by the FRI ACIAR project officer and 4 other research team members who rings, flatten, and slash the site to control grasses from competing with the trees. Maintenance of the site is done every two months or early depending on the dry/wet seasons and how fast the grass grows.

Challenges

Tikeleng trial is located in a water-logged area as a result of the wet weather conditions of Lae, Morobe Province. In mitigating this problem, drainage was constructed after the establishment of the trial to help trapped waters drain out and to encourage run-offs. The site is located north-east of Lae city with two rivers along the way. It is therefore impossible to cross these rivers during wet seasons as there or no constructed bridges.

Location

Buem, Tikeleng, Morobe, PNG

Planting date

13th April 2022

Soil Type

Brown soil (Eutropepts) composed of riverbed sediment deposits (gravel)

Land tenure

Traditional land

Altitude

55 m asl

Rainfall
Annual rainfall 4419 mm

Site Preparation
Clearing and Burning

Weed Control
Ring weeding and clearing

Fertilizer
Nil

Fencing
Nil

Appendix 1

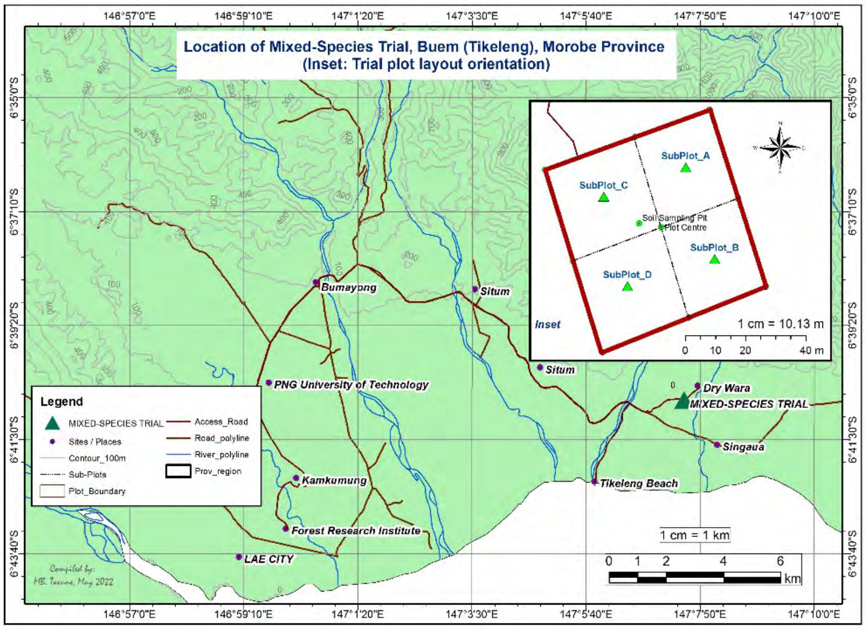


Figure 1: **Location Map**

Appendix 2

Experimental design of the mixed-species trial

Mixed species trial tree planting map

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	
	1	o	o	o	o	o	o	o	o	o	o	o	+	+	+	+	+	+	+	+	+	+	+	
	2	o	o	o	o	o	o	o	o	o	o	+	o	+	+	+	+	+	+	+	+	+	+	
	3	o	o	o	o	o	o	o	o	o	+	o	+	o	+	+	+	+	+	+	+	+	+	
	4	o	o	o	o	o	o	o	+	o	o	+	o	+	+	o	+	+	+	+	+	+	+	
	5	o	o	o	o	o	o	o	o	o	+	o	+	o	+	+	+	+	+	+	+	+	+	
Subplot A	6	o	o	o	o	o	o	o	o	o	o	+	o	+	+	+	+	+	+	+	+	+	+	**Subplot B**
	7	o	o	o	o	o	o	o	o	o	+	o	+	o	+	+	+	+	+	+	+	+	+	
	8	o	o	o	x	o	o	o	□	o	o	□	x	+	+	x	+	+	+	□	+	+	+	
	9	o	o	o	o	o	o	o	o	□	+	o	+	o	x	+	+	+	+	+	+	+	+	
	10	o	o	x	o	x	o	x	o	x	o	+	o	+	□	+	□	+	□	+	□	+	+	
	11	o	x	o	x	o	x	o	□	o	x	□	x	□	+	x	+	□	+	□	+	□	+	
	12	x	o	x	o	x	o	x	+	x	o	+	o	+	□	o	□	+	□	+	□	+	□	
	13	x	x	o	x	o	x	o	x	o	x	□	x	□	+	□	+	□	+	□	+	□	□	
	14	x	x	x	x	x	x	x	x	+	□	x	□	x	o	□	□	□	□	□	□	□	□	
	15	x	x	x	o	x	x	x	+	x	x	+	o	□	□	o	□	□	□	+	□	□	□	
Subplot C	16	x	x	x	x	x	x	x	x	x	□	x	□	x	□	□	□	□	□	□	□	□	□	**Subplot D**
	17	x	x	x	x	x	x	x	x	x	x	□	x	□	□	□	□	□	□	□	□	□	□	
	18	x	x	x	x	x	x	x	x	x	□	x	□	x	□	□	□	□	□	□	□	□	□	
	19	x	x	x	x	x	x	x	□	x	x	□	x	□	□	x	□	□	□	□	□	□	□	
	20	x	x	x	x	x	x	x	x	x	□	x	□	x	□	□	□	□	□	□	□	□	□	
	21	x	x	x	x	x	x	x	x	x	x	□	x	□	□	□	□	□	□	□	□	□	□	
	22	x	x	x	x	x	x	x	x	x	x	x	□	□	□	□	□	□	□	□	□	□	□	

Symbol	Species name
o	*Pometia pinnata*
+	*Homalium foetidium*
x	*Canarium indicum*
□	*Elaeocarpus angustifolius*

The colour-coded symbols: x, o, +, and □, represent the four different tree species.

Symbols that are in '**Bold**' and bordering the plot are the buffer trees.

The blue letters and numbers are grid references to aid in locating specific trees.

Appendix 3

Trial measurement schedule for mixed-species trial

Measurement schedule	Reporting
13th April 2022	Initial height & dgl data
13th July 2022	3 months height & dgl data
13th October 2022	6 months height & dgl data
13th April 2023	12 months height & dgl/dbh data
13th April 2024	24 months height & dbh data
13th April 2025	36 months height & dbh data

TREE SPECIES SELECTION: ONE OF THE COMPONENTS FOR SUCCESSFUL FLR IN PNG

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ABSTRACT: Papua New Guinea has 70% of its population living in rural areas with an increasing dependence on forests and trees. These forested lands are being cleared and burnt for other land uses which has resulted in large areas of degraded grasslands. Restoration of these degraded landscapes is being addressed through a number of public and private tree planting enterprises, which involve tree species that are promoted as having socio-economic values and suitable silvicultural characteristics. These reforestation activities and projects have had mixed results. Part of the solution for improving reforestation performances involves adopting research results that identify the right species for the right sites and includes those with economic end uses and market accessibility. The identification of suitable species was recognised in the early 1960s with the commencement of species trials in East Sepik Province. Some of these trials were established with the aim of identifying species that performed well on degraded sites and had economic values for landowners. This paper provides a summary of growth and yield for selected tree species and provenances from the list of over 100 species trialled between 1965 and 2009. The results of these trials have provided valuable inputs to government sponsor forest and landscape restoration initiatives such as the current "*Painim Graun, Plannim Diwai* '', agroforestry projects and landowner plantings across various sites in PNG. Results have indicated the importance of provenance selection in identification of suitable species. For example, *Eucalyptus deglupta* plantings in Milne Bay where the growth of provenance A was double that of Provenance B at age 17 years. Similarly, on fertile, high rainfall sites near Lae, the growth of *Intsia bijuga* and *Pterocarpus indicus* was 25% less at age 10 years than *Pometia pinnata*, another high value species.

Community-based Landscape Scale Reforestation Initiatives in Asia-Pacific

FST/2016/153: Enabling Community Forestry in Papua New Guinea

Activity 2.1

June 2020

Kanchana Wiset, Jack Baynes and Grahame Applegate

Table of Contents

Review of community-based landscape-scale reforestation initiatives in the Asia-Pacific

1. Executive Summary

This review examines a number of landscape scale community reforestation initiatives in the Asia Pacific region, many of which are designed to improve community livelihoods using tree-based systems. Potential challenges for implementing different types of landscape scale reforestation initiatives involving communities are analysed with case studies from across the Asia Pacific region, with a focus on South-East Asia, parts of central, north and south Asia, and the Pacific. The paper does not focus on large-scale reforestation for short rotation fibre production, which in some cases, such as the 'plasma scheme' in Indonesia, is designed by companies to encourage tree planting to supplement fibre supply to nearby pulp mills.

Reforestation through 'Forest Landscape Restoration' has been promoted as a global restoration initiative by the Bonn Challenge. To date, most reforestation has been initiated to restore degraded or deforested landscapes and this has tended to focus efforts and targets on initial tree planting activities, with little analysis of management or maintenance of the young seedlings, ecological outcomes, or community benefits. The limited literature available looks more at the biophysical aspects of landscape scale reforestation, rather than social aspects. Lack of understanding of restoring forests in the process of sustainably managing rural landscapes without addressing social outcomes does hinder implementation, policy development and the establishment of the necessary institutional frameworks to ensure landscapes are restored. A further gap which was highlighted is the limited number of documented community reforestation activities which incorporate community livelihoods and profitable enterprises. Many such studies are usually reported through the grey literature, published by organisations such as the World Wildlife Fund (WWF), The Food and Agriculture Organisation of the United Nations (FAO) and the International Union for Conservation and Nature (IUCN) and donor funded projects.

In Asia-Pacific, community involvement in reforestation on a landscape scale (large scale) and landscape restoration have been suggested as ways of addressing deforestation, forest degradation and enhancing better forest management by the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) and the Asian Forest Cooperative Organisation (AFoCo). It is clear from the literature and the various schemes involving 'community-based reforestation' that there is no clear differentiation in many countries that are practicing, or have policies relating to community-based forestry, between reforestation on a large or landscape scale and forest landscape restoration, or the role forests play in restoring rural landscapes region.

There are two main approaches to community involvement in reforestation in the Asia-Pacific. They can be described as follows:

1) Government initiated, funded and managed programs, often characterised by large reforestation projects covering the whole country, where communities are engaged mainly for their labour to plant the tree seedlings, with little consultation or collaboration with those whose land is often involved, or who live adjacent to the degrade areas to be forested. Some of these programs have focused on fibre production which is often done in close cooperation with the private sector, while others, usually without much private sector involvement, focus largely on restoration on a large or landscape scale for ecosystem services, and biodiversity conservation. As an example, reforestation, landscape restoration and wood fibre production have been part of forest policy and implemented on very large areas in China and the Republic

of Korea. In other countries in South-East Asia, such as Indonesia, Vietnam, Philippines and in Melanesia, (Papua New Guinea, the Solomon Islands, Vanuatu, and Fiji) community-based reforestation and restoration along with private plantation expansion is part of forest policy. The lessons learned from the reports on large scale reforestation programs indicate that strong local, and in some cases international support, and strong institutional arrangements and finance are the pathways to success. Some of the programs have focused on ecosystem restoration, as is the case of the Republic of Korea to improve social well-being, while the Indonesian Social Forestry program, designed to cover 12.7 million ha is focused on improving local livelihoods. The design and implementation of most of these programs, where they have actually occurred, have been driven by central governments, with little decision making or 'ownership' by local communities, although local people's involvement in the tree planting were essential.

2) Community-based forestry management (CBFM), or community forestry (CF) are two of the many terms that can be lumped under the generic terms CF or CBFM. These terms are often used in very different ways in different countries, sometimes with completely different definitions. CBFM or CF involves either collective action or in some literature, smallholder involvement, that has been implemented in different forms in places such as Nepal, India and the Philippines, and to a lesser extent in Cambodia, Indonesia, Viet Nam and Thailand. Each one of these countries have undertaken CF in different ways as a result of having different political and social situations. CBFM as opposed to social forestry (SF) is a term some organisations have used to describe forestry practised on land that has communal tenure and requires collective action. Smallholder forestry which is forestry practiced by smallholders on land that is privately owned and this also has also been described by some organisations as community forestry. The concept of community-based forestry emerged in the 1970s and 80s in developing countries in response to the lack of socio-economic development of communities from forest industry development models and to improve the integrity of forests. In many places it was designed to be implemented at landscape scale and to enhance gender-equity, the latter of which has had mixed success, often related to local norms and social customs. Secure land tenure for communities has also been neglected in some cases. In Melanesian countries, such as PNG in which land is managed under customary land tenure, governments have often added regulatory and effective commercial control over the level of clan control and this has contributed to the challenges of scaling-up as well as increasing the effective area of planted forests.

Papua New Guinea is one of the most-forested nations in the Pacific region with a forest cover of more than 50 percent of its total area and is the third-largest tropical forested land in the world. Most land in Papua New Guinea is under clan ownership, so the first plantations established in the 1960s was on land acquired by the Department of Forests. Reforestation became part of the National Forest Policy in 1991, to encourage commercial timber enterprises, clans and landowner groups to establish plantations on community land (Srivastava, 1992). In 2003, the parliament endorsed the National Reforestation Policy (Blaser et al., 2011), with the expectation of increasing the area of forest plantations and improving silvicultural management of the selectively harvested natural forests – referred to as '*reforestation naturally'* (Papua New Guinea Forest Authority, 2009). Many of the forest policies appear to address the issues of deforestation and poor forest management, but the financial and economic constraints, geographical isolation, institutional arrangements, land tenure systems, and lack of integrated land use planning and technical and institutional weaknesses at local level continue to impact negatively on communities as the dominant forest and land owners (Wilkie et al., 2002). Some of the concerns relating to landowner or clan mechanisms for participatory decision making, realised benefits to landowners, social, political and cultural dynamics, impact on the ability in many parts of PNG to implement community-based or smallholder landscape scale reforestation and natural forest management (Keppel et al., 2012).

Policy Development

The PNG government, through the Papua New Guinea Forest Authority (PNGFA) promotes a strategy of sustainable forest management in their policies and legal frameworks. However, although most of the land is owned by the clans with strong tenure rights, the government retains the right to issue Forest Management Agreements over forested lands and to provide oversight on harvesting operations, collection of royalties and taxes and distribution of royalties to communities. Hence due to the regulations, clans are prohibited from exercising management of their forests and forested lands. While the PNGFA has set targets for reforestation on both government and clan lands (community forestry), the implementation of such a scheme has a number of impediments relating in part to a reduced emphasis on extension activities at the province level, insufficient budget to meet annual targets on government and community or clan land as well as inconsistences between the policies, strategies and programs. The end result in many places is that the people have generally showed little interest in government reforestation on their clan lands.

Forest restoration and reforestation strategies have moved away from decentralised management in the provinces to a more centralised approach, with a policy focus on large scale private company plantations in response to the demand by government for plantation grown wood. There is little support provided to local communities and small-scale family-based planting programs within clan lands. Currently there are no current specific policies or financial support for landscape scale community-based or clan-based reforestation.

Forest governance

Governance practices in PNG’s forest sector has resulted in minimal enforcement of forest laws and regulations. Communities have had little involvement in the development of forest policies, laws and implementation and in addition, customary landowners are vulnerable to exploitation of their clan-owned forests.

Land resources and customary rights

Despite strong legal customary tenure rights, which are not subject to state control, there have been few attempts to align government regulations with customary land tenure. For example, the government has devised ‘Incorporated Landowner Groups’ (ILGs) to integrate customary landowners in land resources development. However, the effect has often resulted in local people having strong de jure rights, but little de facto rights. In terms of forestry, the PNGFA retains the right to issue Forest Management Agreements, with agreement from the clan and to provide oversight on harvesting operations. Clans are not permitted to exercise management of their forests or on reforested lands, without approval from the PNGFA.

2. Introduction

The Asia-Pacific is the least forested region in the world, having only 0.18 hectares of forest per person (Food and Agriculture Organisation of the United Nations [FAO], 2019a). There was a dramatic net loss of forest cover in many Asia-Pacific countries commencing in the 1990s (the Philippines started much earlier) when harvesting of tropical logs peaked, resulting in large areas of degraded and unmanaged forest land discarded by the concessionaires. This practice continued to 2000, at which time the region had an annual increase of forest cover mainly from plantations of 2.3 million hectares (2000 to 2005), and just under 0.5 million hectares per year to 2010 (FAO, 2010). Increasing the forest area in the region has occurred mainly due to the rapidly expanding planted forests, primarily for fibre production, even though there has been a corresponding decline in the area of primary or natural forest (FAO, 2019a).

The Pacific Island countries, of Micronesia, Melanesia, Polynesia and Australasia have natural forests covering up to 186 million hectares, and planted forests covering about 4 million hectares (FAO, 2011). The most-forested nations are the Melanesian countries (Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia and Fiji), with more than 50 percent of the land retained as natural forest. However, land clearing has resulted in the net loss of 1.08 million hectares of forests in the Pacific between 2005 and 2010, most of which occurred in Australia and across Melanesia (FAO, 2011). Papua New Guinea and the Solomon Islands had the largest loss among Melanesia countries, resulting from land clearing for cultivation and unsustainable industrial logging practices (FAO, 2011). While these data are somewhat outdated, the trends continue (FAO, 2018).

This study reviewed the progress of a number of community-based landscape scale reforestation efforts in the Asia Pacific region and conducted a synthesis on the outcomes, potential and challenges of implementing these schemes in the region. To review the outcomes and challenges of implementing different types of landscape scale reforestation initiatives involving communities, a number of case studies were looked at across Asia Pacific, with a focus on South-East Asia, parts of north, east Asia, and the Pacific. The report does not focus on large-scale reforestation for short rotation fibre production, where in some cases, communities are contracted to supplement fibre supply to nearby pulp mills.

3. Community-based Forestry

Reforestation with and without community collective decision making, commenced more than 60 years ago in the Asia Pacific region in countries such as the Republic of Korea which had been devastated by the war and poverty. The concept of smallholder and community-based forestry began later in the 1970s and 80s. This came about largely due to the perception that the manner in which forest development was being undertaken, did not result in socioeconomic development of local communities and nor did it address increasing deforestation and forest degradation (Gilmour et al., 1989). Since its inception, community-based forestry has been implemented in a number of countries such as Nepal, India and the Philippines (uses the term CBFM), and to a lesser extent in Cambodia, Indonesia, Viet Nam and Thailand in different forms as a result of these countries having different political and social situations. Consequently, a number of definitions have emerged (FAO, 2016). Community-based forestry as opposed to social forestry is forestry practised on land that has some form of communal tenure and requires collective action. It also includes smallholder forestry which a number of organisations wish to include under CF or CBFM, is forestry practiced by smallholders on land that is privately owned (FAO, 2016; Herbohn, 2000). In a number of Asia Pacific countries, such as Indonesia and Thailand, smallholder forestry has become the main form of community forestry. Community forestry has also become a major policy instrument for achieving biophysical outcomes such as increased area of planted forests and improving the socioeconomic conditions of communities and in so doing, has contributed to promoting sustainable forest management (SFM) and improving local livelihoods (FAO, 2016). Community forestry has often been designed to be implemented in a mosaic at a landscape scale and to enhance gender-equity, which has had mixed success that is often related to local norms and social customs. One notable change in counties such as Nepal and the Philippines, is that the management of the areas to be reforested has been devolved to local communities and their institutions for reforestation and forest management, although the government retains control over funds and broad land use planning. Securing the tenure of the land has also been neglected in some cases and unresolved in many others.

4. Sustainable Forest Management

Sustainable Forest Management (SFM) or management of forested land has been practiced by foresters for centuries, commencing in 1165 in the German states (Edline et al., 2020). SFM was a term introduced to address the issues of forest loss and to promote various global practices for increasing forest cover and forest protection, implementing management plans, and encouraging forest management certification (FAO, 2016). The Asia Pacific region also developed SFM policies (Yasmi et al., 2010) and consequently a number of countries introduced a range of efforts to increase forest area (FAO, 2016). Although the Asia Pacific region has about 45 percent of the world's planted forests in 2020, it still has high rates of forest degradation and sub-optimal forest management practices (Asia-Pacific Economic Cooperation [APFC], 2020). To improve on this situation, an expansion of the number of trees growing outside plantations in agroforestry systems has been proposed (FAO, 2010) along with an expansion of protected areas, species and biodiversity conservation areas, and community-based forestry initiatives (United Nations Development Programme [UNDP], 2012).

SFM has had challenges resulting in limited scale (UNDP, 2012) due to overlapping property rights, poor governance, unsustainable logging practices and forest encroachment (FAO, 2010; Yasmi et al., 2010). In addition, the small Pacific island countries are vulnerable to natural disasters, economic constraints, geographical isolation, poor institutional governance, insecure land tenure and a lack of integrated land use planning (Wilkie et al., 2002). At local levels, traditional social, political, cultural influences also dominate (Keppel et al., 2012), thus further reducing the effectiveness of intended programs to improve forest conditions.

5. Forest Landscape Restoration

Growing trees to replace the forest that has been lost may not be the best way to reverse the problem of deforestation, as it does not always address the bigger issue of restoring the landscape. In addition, forest management has shifted somewhat from managing pure forest stands or planted forests for production to include a landscape management oriented approach (Liu & Taylor,2002; Zeki & Ahmet,1999). This landscape approach is designed to reconcile development objectives of the whole landscape, including forested or degraded forest areas with environmental and biodiversity goals (Sayer et al., 2013). This is now promoted as *'Forest and Landscape Restoration' and 'Forest Landscape Restoration'* (FLR) which have also been promoted as a global restoration initiative to implement the Bonn Challenge[1]. While the Asia Pacific has also moved toward FLR, or in most cases, what is practiced is reforestation on a landscape scale, it faces challenges related to large size of the region and cultural diversity (Besacier et al., 2016). The development of specific plans and implementation strategies to support national reforestation targets and improving socio-economic development of each country maybe required as proposed by the Food and Agriculture Organisation of the United Nations (FAO) and the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) (FAO & APFNet, 2018).

In principle, forest landscape restoration, not to be confused with landscape scale reforestation, aims to address forest and land degradation (Stanturf et al., 2017; Uriarte & Chazdon, 2016), by focusing on landscape level land use planning issues and identifying where forests play a role, or can play a role (Maginnis & Jackson, 2007; Mansourian, 2005; International Union for Conservation and Nature [IUCN] & World Resources Institute [WRI], 2014). In similar ways to community forestry, it is designed to incorporate stakeholders' decision making at multiple levels, to achieve sustainable

[1] The Bonn Challenge is a global effort to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030 (http://www.bonnchallenge.org/content/challenge)

landscape level outcomes (Maginnis et al., 2007). FLR differs from reforestation (tree planting), by aiming to promote both social and ecological aspects of forest management where forests are best located or should be re-established, to improve local livelihoods and conserve biodiversity (Mansourian, 2005; Orsi & Geneletti, 2010), within an entire landscape, according to an agreed land use plan (Mansourian, 2017).

To date, most the implementation of FLR has been restoration or reforestation of degraded landscapes (Mansourian et al., 2017), in contrast to focusing on landscape level planning issues and identifying where forests are best suited and tended to emphasize ecological outcomes (Reinecke & Blum (2018). Hence any lack of understanding of the multiple outcomes of FLR, could hinder its implementation and the need for sound institutional frameworks (Chazdon et al., 2017). There is still a lack of knowledge on the part of many stakeholders of how important the planning process is in FLR (Chazdon et al., 2017) along with an agreed understanding of what the landscape would look like through a process of negotiation.

FLR also involves consideration of landscape scale and identification of the landscape boundary and whether to restore a whole area within a landscape to create a balance of benefits of multiple-land uses across landscape (IUCN & WRI, 2014). Nonetheless, it does not mean only the execution at a large scale, it could be site level decisions and actions that are made within a landscape contexts and reach landscape outcomes and FLR objectives (Maginnis & Jackson, 2007; Stanturf et al., 2017). In addition, there is often a lack of consideration that it is process-oriented as it has been often viewed as a project-based. FLR is advocated by the Bonn Challenge Initiative as an ongoing process, (Fisher et al., 2018) which is explained by the word ‘process’ which requires a participatory action, adaptive management and consistent evaluation and learning framework. FLR may not always be a planned process, but it would need an understanding of what the landscape would look like through a process of negotiation, which Fisher et al. (2018) noted that a landscape concept would not be used for centralized planning. These characteristics are issues occurring in many parts of the Asia Pacific region in relation to FLR.

5.1 **Forest Landscape Restoration and Community Forestry**

To obtain a greater understanding of how FLR has been interpreted and reported in the literature to date, a search of ‘FLR’ on the Web of Science and Google Scholar found 130 papers (as of 14 February 2019), most of which emphasised biophysical aspects of FLR rather than social aspects. This fact highlights the lack of understanding by many researchers in confusing reforestation with FLR. The papers mainly discussed ecological restoration, ecosystem services, biodiversity conservation, community-based reforestation on a landscape scale. Approximately 10 % of the studies related to the Asia Pacific, with most of the literature related to the United States (29%), Brazil (11%) and Australia (8%). The remainder were reviews and discussions of the concepts of FLR involving community perspectives and local livelihoods. The study by Adams et al. (2016) also found a similar result, that 60% of the studies emphasised large-scale and landscape scale and national level reforestation initiatives (not necessarily FLR), while only 29% of papers discussed community-based initiatives for landscape scale reforestation.

Despite the paucity of published literature, there have been various community-based reforestation efforts often supported by development agencies, conservation organizations, and government projects. These initiatives have been documented in project reports and as a result most of the case studies found in the grey literature are published by research and development organizations. These organizations include the Centre for International Forestry Research (CIFOR), EcoAgriculture Partners, Food and Agriculture Organization of the United Nations (FAO), International Union for Conservation of Nature (IUCN), International Union of Forest Research Organizations (IUFRO), Landscapes for People, Food and Nature Initiative, RECOFTC – The Centre for People and

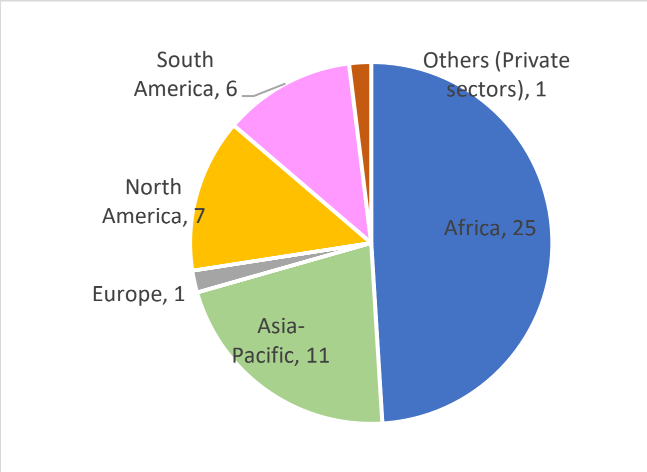
Forests, Terrafrica, The World Bank's Program on Forests (PROFOR), World Agroforestry Centre (ICRAF), World Resources Institute (WRI) and World Wildlife Fund (WWF).

In summary, the literature from both peer-reviewed papers and the grey literature revealed the low level of progress in relation to understanding and implementing community forestry and FLR in the Asia Pacific region (see Appendix 1).

Micah Scudder in discussion with landowner Mr Phillip Wago at Morobe on issues related to community forestry. Mr Mac from TFTC (left of photo). Mr Wago also has cocoa plantings using grafted clonal material which produces beans within 1 year of planting. Photo Grahame Applegate

6. Community Forestry in Asia-Pacific

Over 50 countries have committed to the Bonn Challenge (Besseau et al., 2018), with a total of 171.71 million hectares pledged, as shown in Figures 1 and 2. In Asia Pacific, 11 countries have pledged to restore or reforest 25.91 million hectares. Those countries are Armenia, Bangladesh, Georgia, India, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Sri Lanka, Tajikistan, and Uzbekistan. In addition, APEC committed to increasing forest cover in the region by at least 20 million hectares by 2020 (APEC, 2017).



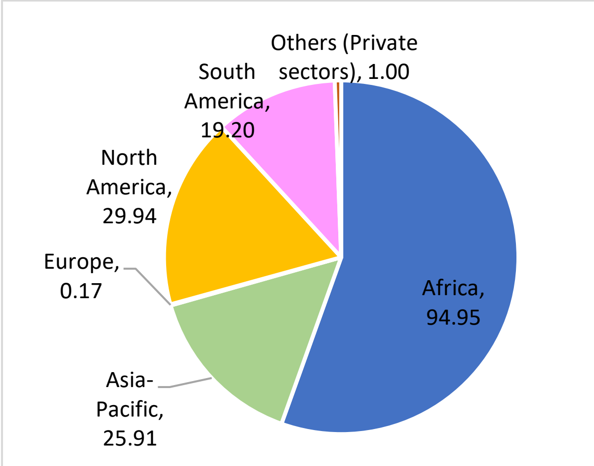


Figure 1 and 2: Commitments to the Bonn Challenge by the number of countries and the area (million hectares) of land pledged for restoration or reforestation.

To enhance the restoration and reforestation efforts in the Asia Pacific, many organizations including, Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet), and ASEAN-ROK Forest Cooperation (AFoCo) and FAO, established the initiative called '*Forest and Landscape Restoration Mechanism (FLRM)*'. This mechanism is designed to assist countries to undertake reforestation, rather than landscape restoration efforts to meet global targets. An FLRM regional strategy was launched at the 23rd Session of the Committee on Forestry (COFO 23) in July 2016 (Chen, 2016). APFC endorsed the *Regional Strategy and Action Plan for Forest and Landscape Restoration* (Besseau et al., 2018) as seen in Box 1.

Box 1: Asia-Pacific Regional Strategy and Action Plan on Forest and Landscape Restoration to 2030 (APFLR)

This is a regional strategy primarily covering the member countries of APFC. It contains of the six strategic priorities and actions as follows;

- Strategic priority 1: Support the development and implementation of national FLR plans and targets
- Strategic priority 2: Promote regional dialogue, learning, collaboration and coordinated action on FLR
- Strategic priority 3: Build recognition for and support the use of various technical, social and institutional approaches as appropriate for different landscapes and restoration objectives
- Strategic priority 4: Facilitate and support the mobilization of financing for FLR
- Strategic priority 5: Encourage private sector participation and investment in FLR
- Strategic priority 6: Support community-level action on FLR

(FAO and APFNet, 2018).

Between 1990 and 2015, the area of planted forest in the region increased from 69 million to 126 million hectares (FAO, 2019a). Annual gains in forest area (particularly plantations) between 2010 and 2015 were highest in China (1.54 million hectares), Australia (0.308 million hectares), Philippines (0.240 million hectares), Lao PDR (0.189 million hectares), India (0.178 million hectares) and Viet Nam (0.129 million hectares)(FAO, 2016).
In the last three decades, much of the forest planting programs for restoration of degraded forests, improving community benefits and short-term fibre production have been implemented by the private sector. With support from government-led programs, the communities involved have often benefited from provision of low-cost seedlings, loans and grants, tax concessions and technical support, in an attempt to engage relevant stakeholders to participate in the plantation efforts (Enters et al., 2003).

Restoring deforested land with forests involving communities is not a new initiative in this region, with a number of countries having developed their own nationwide reforestation, forest rehabilitation and restoration programs commencing in the 1970s, with the results still very evident 45 years later (FAO & APFNet, 2018).

For Pacific Island countries, the key sub-regional forestry cooperation network is the Pacific Community (PC), which has helped the Pacific countries develop their human and natural resources (FAO, 2019a). Under the PC, the Land Resources' Division (LRD) aims to develop improved land management practices in agriculture and forestry, aiming for better solutions for endangered forests and landscapes as well as for vulnerable communities.

FAO is another key agent in helping the Pacific Island countries to develop their restoration efforts. In a recent development in the Pacific, FAO and their partners organized *a 'Workshop on the Sub-regional Exchange for the Pacific on the Restoration of Forests and Other Ecosystems within Landscape Approach: Assessing needs and opportunities for regional ambition'*, on 28–30 May 2019 in Fiji. This workshop aimed to support the governments and relevant organizations in the Pacific to develop and implement their national plans related to the restoration of forests and other ecosystems using a landscape approach (FAO, 2019c). Key outcomes to assist forest restoration in the Pacific included an assessment of gaps and establishment of targets for reforestation and community-based targets for restoration. The four priorities for restoration interventions and the brief details are in Box 2.

Box 2: Potential Restoration Interventions in the Pacific

Key messages as outcomes of the Nadi workshop (held between May 28th and 30th, 2019) identified the potential restoration interventions in the Pacific, covering the four areas as follows:

1) **Community engagement:** Engagement of community is a key, as the lands are owned by local people. Key methodologies to ensure their engagement are such as community profiling and participatory land use planning. Existing social structures should be considered for communicating restoration's objectives.
2) **Assisted National Regeneration (ANR):** ANR could be a part of an overall land use planning approach at the landscape scale and it is a very cost-effective way for restoration. To promote a successful of ANR, it needs to cope with fires and invasive species, and to overcome the cultural bias against *'leaving the land disaffected'*.
3) **Agroforestry:** It is a potential option to be promoted in helping to generate a wide range of environmental and social. Demonstration plot establishment is a useful mechanism to convey and build the understanding of communities for undertaking agroforestry practices. Agroforestry is cross-cutting, requiring the coordination between the ministries of environment and forestry and agriculture.
4) **Mangrove restoration:** Technical and scientific knowledge needs to be strengthened. Specific legal and policy frameworks need to be developed. Some countries have had various degrees of success but they need to be the assessed.

(FAO, 2019b)

6.1 **Community forestry – selected examples of large-scale government initiatives**

Implementation of large-scale reforestation in Asia Pacific countries has resulted in an increase in forest cover of the region. Many of these reforestation activities designed to reforest deforested areas are government initiated, funded and managed. These activities are often characterised by being large in scale where communities are engaged mainly for their labour, with little consultation on collaboration or planning input by the local communities whose land is often involved or who live adjacent to the areas to be forested. Some of these programs have focused on fibre production which is often done in close cooperation with the private sector, while others, usually without much private sector involvement largely focus on restoration of the forests for ecosystem services, and biodiversity conservation. Reforestation, landscape restoration and wood fibre production have been part of forest policy and implemented, most notably in China and the Republic of Korea and in a number of countries in South-East Asia, such as Indonesia. In Melanesia, (Papua New Guinea, the Solomon Islands, Vanuatu, and Fiji) countries have also identified reforestation and restoration in their forest policies by emphasizing private plantation expansion. Some of the programs have focused on ecosystem restoration, as is the case of the Republic of Korea, to improve forest cover and social well-being, while the Indonesian Social Forestry program which is designed to cover 12.7 million ha of largely degraded land is focused on improving local livelihoods. However, many of these programs have an emphasis on plantation establishment of fast-growing species for timber production.

The main characteristic of most of these programs is that they are driven by central governments, with little decision making or 'ownership' from local communities, although local people's involvement in labour in the planting etc are essential for their success. The lessons from those large-scale programs indicate that strong local government, and in some cases international support, and strong institutional settings at the local and central level and adequate finance are the pathways that have led to their success in re-establishing forests.

Example of some of these reforestation programs which are often described as community forestry programs are as follows;

- **China:** China has placed substantial emphasis and funding efforts for forest restoration and conservation programs in the country since 1978 (Cao, 2011). For example, the *Three Norths Shelter Forest System Project (TNSFSP*) planned for 30.6 million hectares of afforestation across 13 provinces, and *the Grain for Green Project (GFGP)* aimed to convert 147 million hectares of farmland on steep slopes into forests and 173 million hectares of grassland into forests in 25 provinces (Cao, 2008). *The Natural Forest Protection Program (NFPP)* was introduced in 1998 and involved 17 provinces of the upper Yangtze River, the upper and middle of the Yellow River and the Northeast and Inner Mongolia areas (Xi et al., 2012). The NFPP also promoted the protection of 92.6 million hectares of forest, increasing the net standing stock to 186 million m^3 and imposing a ban on commercial harvesting in the natural forests in 13 provinces.

- **Republic of Korea (ROK):** In the early 1960s, forests covered less than 40% of the land with deforestation a major problem caused mainly by many years of war and poverty. In the 1970s, the central government expanded its reforestation program which focused on fuelwood production and watershed protection and integrated it with a broader economic development plan comprising a national reforestation program to restore the forests destroyed during the Korean war. While the species planted were few, the result has been a doubling of the standing volume in the forests in 14 years from 13 m3/ha in 1973 to 32 m3/ha in 1987 (Bae et al., 2012). The program was based on an integrated policy of land management and social development to address flooding and erosion issues due to deforestation, as well as to enhance economic growth and the well-being of communities living adjacent to the forests (Park & Youn, 2017). The Koreans also used a combination of forest protection and forest management technologies including forest survey and inventories, tree improvement, seeding and high-quality clonal nurseries, tree planting, tending (forest maintenance), and pest control (Park et al., 2017). The planting was undertaken by various parts of the community, including individuals and youth groups organised by local governors and mayors who mobilised the various local communities. It should be noted that currently the government of the Republic of Korea as a matter of government policy is using tree planting and reforestation as a means of promoting peace with the Democratic People's Republic of Korea (North Korea) by providing high quality seedlings and technology to North Korea, using a similar approach to reforestation as was undertaken following the devastation of the landscape in the Republic of Korea in the 1950s and 60s.

- **Vietnam**: The government of Vietnam initiated two significant restoration programs – *the Greening the Barren Hills Program and the 5 Million Hectares Reforestation Programme* (5MHRP) (FAO & RECOFTC, 2016). The Greening the Barren Hills began in 1992 to restore the degraded lands in the highland region, by establishing 600,000 ha of planted forests, enriching 700,000 ha of existing forests, and supporting state owned forestry enterprises (de Jong, 2010). Following the 5MHRP, the program established 3 million ha of production forests and planned to restore 2 million ha of protection forests, through local community involvement (de Jong, 2010).

- **Philippines:** The government of Philippines began reforestation activities in the 1970s and modified their approach in 1989 with the introduction of a contracted reforestation scheme (Gerritz, 1996). This was followed by the National Reforestation Scheme to 2000 along with many other variations as outlined in Harrison et al. (2004) Two major national programs were introduced in the first decade of 2000, namely the Community Based Forestry Management (CBFM) program and the Community Based Resource Management (CBRM) program. Following on from these programs, the government endorsed the *'National Greening Program (NGP)'* forest restoration program that aimed to restore 1.5M ha from 2011-2016 (Balangue, 2016). The program was expanded as *'Expanding the Coverage of the National Greening Program (ENGP)'*, to restore an additional 7.1M ha of open, degraded and denuded forest land from 2016 to 2028 and then extended it to include an additional 2.4M ha within the remaining 7.1M ha of lands available for reforestation (FAO & RECOFTC, 2016). The NGP is a key initiative of the government aimed at poverty reduction, enhancing the environment, climate change mitigation and adaptation (Israel, 2016). The NGP is a government-funded forest restoration program which is implemented mainly through the People's Organisations (POs) established in the villages concerned (also referred to as 'communities'). The POs are the primary implementers of the scheme as almost all of them have land tenure (Community-based Forest Management Agreements or CBFMAs) provided to them when they were formed to implement the earlier CBFM Program, prior to the implementation of the NGP. The CBFM sites, which 'failed' in the reforestation efforts were then selected as priority sites for the NGP from 2011-2014. The more recent NGP plantings are situated outside the CBFM areas. However, the CBFM agreements remain as the platform for the reforestation programs in the Philippines. The NGP is "piggy-backing" on the CBFM, although these two programs are managed by different sections of Department of Energy and Natural Resources. This is one of the reasons why the NGP scheme has largely been unsuccessful according to the Philippines Commissions of Audit (Commission of Audit, 2019). The main difference in the two "community based" programs is; i) the NGP was not designed to be a forest landscape restoration scheme and ii) the NGP does not include several essential elements for community-based forest restoration including; a) community-organising, b) capacity building of smallholders, and c) many livelihood projects are mostly government-designed. The NGP does follow the planting zones established under the CBFM along with the process of utilising planted trees based on the Community Resource Management Framework developed by the POs under the CBFM. The concept of CBFM has more of the principles related to FLR, although the implementation is very different, as it is fundamentally a government contracted reforestation scheme, i.e. villagers are paid to undertake reforestation activities, which mainly focuses on nursery production of a few species and the planting of the tree seedlings they produce.

- **Indonesia:** From the 1970s, Indonesia's forest management initiatives have been impacted by issues related to poverty, land tenue conflicts and forest degradation, with communities excluded from having any role in managing forests. Villagers were mainly seen as low-cost labour for the expanding plantation sector. Not much had changed since the 1950s, when Dr Hatta, Vice President of Indonesia at the time wrote that Indonesia was a 'nation of coolies and a coolie among nations' and that reform and development was needed for its 70 million people (Hatta, 1957). From the beginning of the 1990s, there has been some changes in attitudes, due to a growing pressure, as there had been in other nations in Asia, for communities living in or adjacent to the forest to be involved in forest management and to derive part of their income from forests (Gilmour, 2015). Commencing in 1995, forest land or the National Forest Estate, mainly the Production Forest was handed to communities for specific purposes by the District Governments (this followed Decentralisation) (RECOFTC, 2013). In 2007, the Ministry of Forestry began to provide legal access and the rights to use forest products, with a number of regulations designed to empower communities to undertake forest management of certain types of forest within the national forest estate (Ministry of Environment and Forestry, 2018). The Social Forestry Program was subsequently established with a target of 12.7 million hectares of forest land to be provided with legal access under six community-based management categories using a concession and licencing system managed by the Ministry of Environment and Forestry. The concession system was similar in design to that used by commercial forestry companies that also operate within the national forest estate under licence for which they pay large fees. The number of concession licences increased significantly within the Social Forestry Program, with large increases in the permits issued for Village Forest, (*Hutan Desa-HD*), Community Forests (*Hutan Kemasyarakatan-HKm*) and Community Plantation Forests (*Hutan Tanaman Rakyat-HTR*) between 2015 and 2018. However, there has been little published analyses of the impacts of some of the initiatives within the program on increasing livelihoods and reducing poverty, even for concessions that have been operating for 13 years. Although the program has ambitious goals, the various capitals required by the villagers themselves to undertake the activities is quite variable, with the very poor communities having little knowledge and few skills (Irawanti et al., 2014). Much of the reporting on the Social Forestry Program to date has been focused on the type of licence issued, area of the permit, along with the number of households who can potentially gain access, primarily to Production Forest land.

- **Pacific Island Countries:** There are no significant or large-scale government sponsored and funded operational community forestry programs being implemented in Melanesia. However, each country has developed reforestation initiatives within their national forest policies providing some support to small-scale reforestation projects. A selection of large-scale government reforestation plans and programs in the Pacific are as follows:
    - **Papua New Guinea:** Given that most land in Papua New Guinea in under clan ownership, the first plantations commenced in the 1960s on land that was acquired by the Department of Forests. Since the 1990s, the Papua New Guinea Forest Authority (PNGFA) has had a policy for supporting forest plantings on clan land and government owned land, with an estimated area of planted forest of about 60,000 ha in 2016. A more detailed account of community- based forestry in PNG is in Section 7.

    - **Fiji:** The government started planting *Swietenia macrophylla* on community land in the 1950s to produce timber suitable for the production of veneer and plywood. Land for plantations was leased from the Native Land Trust Board, with annual rents paid to landowners along with a percentage of the stumpage at harvest. By 1992, the Fiji Pine Commission, a semi government organisation, had acquired over 53,000 ha of land dominated by *Pennisetum polystachyon* (mission grass) for large scale *Pinus caribaea* and *Swietenia macrophylla* plantations (Blaser et al., 2011). The government also developed at this time the Rural Land Use Policy, with the aim of increasing afforestation and reforestation by 20 percent (Alfred & Osea, 2010).

      Vanuatu: Vanuatu had about 1,800 ha of plantations primarily of *Cordia allodoria* in 1990, after 450 ha were destroyed by Cyclone Nigel in 1985 (Neil & Barrance, 1985). The plantations were established primarily by the government on land acquired from communities by the Forestry Department (Evans, 1992). Prior to the National Forest Policy being prepared in 1997, which advocated more reforestation and strengthening of natural forest management (Department of Forests, 2001), some individuals and land owners planted fast growing species of Whitewood (*Endospermum medullosum*) with the timber planned for the Japanese market. Very little planting is currently undertaken now in Vanuatu, with the exception of sandalwood.

- **Solomon Islands:** Forest plantations covered about 25,000 ha of the country in 1992 (Evans, 1992) and comprised *Pinus* sp.*, Swietenia macrophylla, Tectona grandis* and *Eucalyptus deglupta*. These plantations were established by the government on land acquired by the Department of Forests. The plantation estate in 2011 was estimated to be 35,600 ha with 80% comprising industrial plantations dominated by 3 companies and located mainly in Western Province (Ministry of Forestry and Research, 2013). British aid developed large areas of *Gmelina arborea* following logging on Kolombangarra, with other companies following suit or taking over land previously planted by the communities funded by the government under various aid development projects. Under the Coalition for National Unity and Rural Advancement (CNURA), the government's policy goal for the forestry sector is to be a key *'sunrise industry'*, with an emphasis on the development of a strong policy on reforestation of logged areas and establishment of smallholder plantations (Pauku, 2009).

One of the common factors relating to community-forestry in the Pacific, is the lack of up-to-date reliable data on areas of viable plantations and communities involved. However, it is apparent that many countries provide little support on the ground for community-based forest management or smallholder forestry.

6.2 **Community forestry –selective examples of community collective action and smallholder initiatives**

Currently, community forestry initiatives in Asia Pacific are not only environmental projects, but have tended to move towards projects that have a wider set of goals supporting environmental, economic, cultural and political objectives (RECOFTC, 2013). Community forestry development in the region has been undertaken using a diversity of approaches which have varied from country to country (Fisher, 2014). Community forestry has a long history in Asia Pacific for over 50 years and has been successful in many countries for a number of years, based on the involvement of communities in reforestation and forest management (FAO, 2010). Forest policies of some countries have empowered communities to implement community-based forestry in Nepal, India and the Philippines, while strong policies to support community forestry were initiated in Cambodia, Indonesia, Viet Nam and Thailand (Yasmi et al., 2010).

The following examples highlight community forestry initiatives in the region.

Nepal: Community forestry which many consider as the birthplace of community forestry in Asia Pacific, commenced its humble beginnings in Nepal in the 1970s. It has changed considerably since the National Forestry Plan was prepared in 1976 to alter the tenure of much national forest land to 'Panchayat Forests'. In 1978, Nepal then introduced rules and regulations to legitimise community forestry. As Don Gilmour wrote in his unpublished 'Retrospective and Prospective View of Community Forestry in Nepal'. *"The first formal community forestry policy framework (The Panchayat Forest and Panchayat Protected Forest Rules and Regulations, 1978) recognised two distinct forms of community forest. Panchayat Forests (PF) were to be plantation forests which were established on largely bare land by communities, and subsequently protected by them. Panchayat Protected Forests (PPF) were degraded natural forests which were to be rehabilitated primarily by community protection efforts. Income generated from PPFs was to be shared between the community and the Government*".

The initial focus was on developing forests largely with donor assistance, particularly in those districts that were deforested, as it was commonly believed that these forests in the middle hills had been destroyed deliberately by the community. Hence many were sceptical that communities could protect forests. While large areas of forest were established on community land (PF and PPF), there was a real impetus in community forestry once the existence of indigenous forest management systems became known (Fisher, 1989; Gilmour & Fisher, 1991). This resulted in a move away from the Panchayat system to what has now become known as Forest User Groups (FUGs) with Guidelines for Implementing Community Forestry prepared in 1989. The Forest Act in 1993, following the revolution in 1990, provided the enabling conditions and legislation for a major leap forward with the assistance of NGOs towards policy advocacy and services with a focus on the way community forestry was developed in the 1980s, resulting in a large areas of community managed forests. Fisher et al. (2018) noted FUGs are established by local institutions, based on negotiations around the uses and management of resources between community members and the Department of Forests. This process enhanced the improvement of forest quality and cover and increased the available resources and access to forest products to local communities. This change in the forest, largely resulted from transferring the management responsibilities and rights over forest resources and products to the FUGs for conserving and managing the degraded hill forests (FAO, 2010). By 2013, more than 18,000 FUGs were managing 1.7 million ha of forests, accounting for one-third of the country's forest area (RECOFTC, 2013). However, Devkota et al., (2018) argued that although CF policy started to deliver socio-economic benefits, there was evidence of the challenges for contributing to livelihood improvement and poverty reduction. Studies found that due to the traditional power structures, the CFUG committees and the decision-making process were dominated by the elites and rich people, overlooking the interests of vulnerable groups such as poor, women and disadvantage individuals.

However, by the late 1990s, as the legitimacy of the Government came under threat internally, resulting in the restricted movements of Government forestry officials and their functions with the user groups in relation to their operational plans. This situation has continued over time and has stifled community forestry as it was first developed. The issue going forward is whether the Government will be able to revert to its role of developing standards for implementing community forestry and allow implementation to be undertaken by civil society and communities.

India: The key community forestry program in India is the 'Joint Forest Management' (JFM) (Yasmi et al., 2010) which was initiated in the 1970s (RECOFTC, 2013). The policies and guidelines for the program were made part of the Indian National Forest Policy in 1988 with guidelines prepared in 1990 and revised in 2000. The concept of the program is a joint venture involving cooperation and collaboration between local communities and the state government and involves both a top-down and bottom-up approach for the protection of the forest from fire, illegal grazing and logging. In return, the communities are permitted to harvest non-timber forest products, which are often of low value (Patra, 2015). The scheme has been adopted in 26 states with over 100,000 forest protection committees established by 2010 and managing of 22 million hectares of degraded forests (RECOFTC, 2013). There are spatial differences in the success of the program with states and regions within states having quite disparate outcomes (Patra, 2015).

Indonesia: Community forestry has been used as a part of democratization process, with the **'***Hutan Kemasyarakatan'* (HKm) initiative being introduced in 1995 by the Ministry of Forestry, allowing the district governments to grant licenses to communities in parts of the national forest estate, but not in the conservation zone (RECOFTC, 2013). The country then developed Regulation PP6 in 2007, identifying new schemes for enhancing a legal registration of community forests and establishment of village forests (*Hutan Desa*) (RECOFTC, 2013). However, while these government schemes have in some places increased community involvement in forest management and perhaps incomes, it is community forestry based on smallholders where most gains have been made. This form of community forestry is practiced by villagers operating on their own land which in many cases where it has been successful, security of tenure is assured by land title. In many areas in Indonesia, smallholders are now producing not only high quality timber from species such as *Tectona grandis*, grown on small plots, but are also focusing on short rotation fast growing species such as *Falcataria moluccana* (native species to Indonesia) which is often grown in agroforestry systems in small areas for pallets and plywood cores to support the manufacturing industries close-by in Java and the plywood mills in Kalimantan (Race & Wettenhall, 2016).

Thailand: The Royal Forest Department (RFD) started preparation of a Community Forestry Bill in 1991, aiming to encourage the participation of local people in managing forests in buffer zones in and around the national forest reserves (Yasmi et al., 2010). However, the passing of the legislation which was first drafted more than 30 year ago has been a lengthy process with several revisions. During this period, community forestry has been practiced widely with much support from NGOs and academics, but such practices have an unclear legal framework (Fisher, 2014). In 2019, the Community Forest Bill was approved by the National Legislative Assembly (NLA), resulting in legal rights over the 'community forests', of which there are some 14,000 of unknown size and location (Bangkok Post, 2019). Although this recent bill would allow communities to manage forest resources and encourage good conservation efforts, forest resources are still under the control of the state. Over utilization of resources and the law may not enhance stronger land tenure security which would benefit local communities (Chandran, 2019).

Cambodia: The Forestry Law 2002 supports the rights of the Forestry Administration to set up community forests and later approved the Sub-Decree on Community Forestry Management in 2003 and the Guidelines on Community Forestry in 2006. This legislation was designed to strengthen community forestry development (Yasmi et al., 2010). Currently, there are community forests covering more than 420 sites, with an area of 400,000 ha of forests (Yasmi et al., 2010). Little is known of the quality or sustainability of these forests.

Philippines: The country has been involved in people's participation in forest management for over 50 years (Blaser et al., 2011). Many government programs have moved toward community forest development, e.g. Integrated Social Forestry Programme (1982), Community Forestry Programme (1989), Low income Upland Communities Project (1990), and the long term program called *'Community-Based Forest Management Programme'* (CBFM) in 1995 (Hartanto, 2007). CBFM has been implemented until recently under the Community-Based Forest Management Agreement (CBFMA), giving the rights to People's Organizations for 'managing' forestlands for up 25 years, which is renewable for another 25 years based on the performances of their management (Emtage, 2004; Lasco et al., 2010). The NGP has gone on to replace CBFM, but as described previously, it is a government-driven, funded and managed reforestation scheme on government forest land.

Pacific Island Countries: Community forestry has developed slowly in both Polynesia and Micronesia, despite the fact, that in most of these countries, the land is owned by the clans or communities. Most of the 'community forestry' field activities involving the participation of local people has been in establishing and managing forest plantations or planted forests. Papua New Guinea will be discussed in Section 7.

Fiji: Fiji is in its infancy of developing community forestry, within its customary land tenure system (Alfred & Osea, 2010). Some of community forestry projects such as the Drawa Block Sustainable Forest Management Project and the Sovi Basin Conservation Project were designed to practice SFM, but both projects were plagued by land conflict issues, particularly regarding ownership, tenure and property rights within forest management areas (Murti &

Boydell, 2008). Once again, it can be seen that the process did not involve collective decision making, with the main controls coming from outside the communities involved. Another recent program is the Reforestation of the Degraded Foothills of the Sugar Belt (REFOREST), which was undertaken over four years from 2014-2018, funded by the European Union (EU) (European Union External Action, 2018). The project aimed to improve watershed management and local livelihoods by empowering people to participate through reforestation. It was a reforestation project with the aims and objectives arrived at from a top down approach and with little or no collective action on the part of the community or smallholders.

Solomon Islands: The Ministry of Forestry (MoF) supports family-based reforestation initiatives and encourages community-based portable and small-scale sawmilling and eco-timber production (Pauku, 2009). In a similar approach to many other Pacific countries, the families or communities are not making management decisions as they should in a community-based forest management system on their community or clan land, but respond to the management directives and legislative arrangements imposed by the MoF.

Vanuatu: This country is in a similar situation with the rest of the Pacific, in that there is no specific policy regarding community forestry as it relates to collective action on the part of communities over management of their land. A pilot community forestry called '*Mangaliliu Community Forestry Project'* (MCFP), supported by the New Zealand government was developed and promoted plantation establishment by local people. The project aimed to mitigate the environmental impacts of *Cordia alliodora* regeneration and generate job opportunities and sustainable livelihoods for men and women at the community level (Department of Forests, 2001).

6.3 **Lessons learned from Community Forestry in Asia-Pacific**

Community forestry as defined by many should be based on collective decisions and actions on community owned or allocated land, or involve smallholders making land use decisions on their own land. The normative definition of community forestry is forest management based on secure tenure rights, strong governance, involves effective participation and collective decision making, improving livelihoods, generating multiple benefits and development of community capacity and strong institutions (Gilmour, 2016; Gritten et al., 2018). Hence, community forestry in the region could potentially support the development of landscape scale reforestation and FLR (Gritten et al., 2018). Unfortunately, community forestry has taken a long while to develop and the evidence from Nepal, where it all began, suggests that it actually results in poverty alleviation, is mixed (Gilmour, 2016). As can be seen in many communities managing their forests in Nepal for example, successful community forestry may be very dependent on the acceptance of a legitimate government and in its absence, 'second generation issues' may occur, suggesting another paradigm shift may be required for supporting and implementing community-based forest management in the future where these situations exist.

6.3.1 Governance

Charnley and Poe (2007) pointed out that strong governance is critical to the success of community forestry. Many examples in the region have been seen to be participatory (RECOFTC, 2013), and have created a high degree of autonomy of local communities in decision-making (Chhatre & Agrawal, 2009), with a number also being gender blind (Fisher, 2014). Although case-studies from south Asia show more cooperation and involvement of women in decision-making of forest management (Agarwal, 2009), some community forestry programs have excluded women because of gender behavioural norms and social customs (Agarwal, 2001; Mai et al., 2011). These norms and cultural systems could limit women's access to resources (Kiptot & Franzel, 2012), and prevent women from exploiting and being involved in resource management (Fonjong, 2008). In addition, customary roles could dictate decisions on land assets, which mostly favour men in a number of countries in Asia Pacific and discourage women's involvement in decision-making (Nijbroek & Wangui, 2018).

6.3.2 Collaborative and adaptive processes

Collaboration and adaptation to changing situations are key principles of what is involved in FLR and community forestry (Besseau et al., 2018) and is often reported as Adaptive Collaborative Management (ACM). Fisher et al. (2007) found that the ACM approach in Nepal, India, the Philippines and Indonesia, could lead to changes in institutional management, human, social, physical and financial capital, as well as creating social learning and collaboration. Community empowerment was a key aspect of the Livelihoods and Landscapes Strategy (LLS) of IUCN, reported by Barrow et al. (2012). Similarly, community-based reforestation in the Phewa watersheds in Nepal, empowered community organization's capacity to implement forest management, within the limitations imposed by the government (Paudyal et al., 2017).

6.3.3 Secure land tenure

Secure land tenure is basic for viable community forestry and FLR to be a viable and sustainable form of land management. Community forestry in most Asian countries is 'administered and managed' by the state, with various levels of usufruct rights limited by a recognition of permanent rights and the granting of community forest tenure mostly for a short time or with limitations (Fisher, 2014). Community forestry could be used as a mechanism to move forward the extension of tenure rights, decision-making powers and, decentralization to rural people and recognition of indigenous peoples' claims (RECOFTC, 2013). For example, community forestry in the Barobbob Watershed, in the Philippines established land ownership certificates and rights over the planted products which motivated farmers' participation (Combalicer et al., 2007). In the Miyun Watershed in China, a timber harvest quota was given to local communities over a defined land use zone, allowing them to access and use the resources in the watershed for their living (Barrow et al., 2012).

However, most Asian countries have State controlled tenure on forested land, even those that report they have community-based forest management. In Melanesian countries (e.g. PNG, Vanuatu and the Solomon Islands), in which land is owned under customary land tenure, governments maintain management and land use decision rights over the land for commercial purposes. Hence, security of land tenure for communities must be addressed for community-based forest management to be successful (Sayer et al., 2015).

6.3.4 Livelihood development

Community-based decision making and collective action in relation to forest management is designed to improve community control over forest resources as well as improving forest-based livelihoods. Experiences from the IUCN LLS program showed that increasing income and livelihood options of local people, (e.g in Doi Mae Salong, Thailand, and the Pathumphone District in Lao PDR, were critical to the success of the community based FLR program (Barrow et al., 2012). In India, motivation of farmers was increased through employment in nurseries and plantation management (Saigal et al., 2016). Villagers also perceived an increase in food production through the restoration programs in the Phewa Lake watershed (Paudyal et al., 2017). Agroforestry has also been successful for community forestry in the Philippines where these activities concentrated on generating additional income (Camacho et al., 2007; Gregorio et al., 2015), and in Doi Mae Salong, Thailand (Barrow et al., 2012). Alternative economic opportunities which create ecotourism, can also be successful, but are very site specific (International Model Forest Network,2016; Mansourian & Vallauri,2012a).

6.3.5 Technical capacity

Local organizations in the rural regions of Asia Pacific usually have little or poor capacity to manage their finances and also lack the required institutions in their communities. This situation often leads to undemocratic and inequitable benefit sharing among community members, which in turn can lead to conflict within the community. For example in the Philippines, a lack of clear benefit sharing among the members of the People Organization who were involved in CBFM, discouraged members' participation (Camacho et al., 2007).

Another important advantage is knowledge improvement of the local people. For instance, all community-based landscape restoration projects implemented by IUCN (Barrow et al., 2012) and WWF (Mansourian & Vallauri, 2012a) raised awareness of local stakeholders and helped to develop a better understanding and improved attitude for managing forest resources together and increasing their perception of forest values and conservation.

6.3.6 Scaling up

The long history of community forestry in Nepal shows that the scaling up process requires changes in policy, based on 'policy experiments' (Fisher, 2014). However, lack of political will results in poor performance and expansion of community forestry in many cases (Gilmour, 2016). Active participation of local people and cooperation of relevant stakeholders has tended to decline after projects finish, as in other countries, e.g. in the Philippines (Camacho et al., 2007; Gregorio et al., 2015) and in Doi Mae Salong, Thailand (Cadena et al., 2014). Therefore, community forestry should not be introduced as a 'project' that is implemented, but should be founded in policy and institutional changes at the national and local levels. Monitoring and evaluation systems are also needed (Mansourian & Vallauri, 2012a) with most FLR programs/ projects often implemented at a small-scale and not tested at a landscape scale (Mansourian et al., 2017), which becomes challenging for increasing the area under community forest management as well as the number of communities involved in community forestry. The potential for scaling up in places such as PNG have additional issues as explained in Section 7.

7. Community Forestry: Papua New Guinea

This section has been prepared to highlight some of the research findings about what is referred to as 'community forestry' in Papua New Guinea (PNG), which has developed in two main streams, are directly related to the nature of forest or land resources in which communities dwell and have access, namely:

- 'Ecoforestry' on community owned native forest, referred to by many as "community ecoforestry". It relates largely to smallholders aiming at sustainable small-scale harvesting of native forests for commercial purposes.
- Reforestation or agroforestry on community owned lands, referred to here as "community-based reforestation.

While almost all of PNG's forests and land are owned by customary landowners, very few realise the economic benefits potentially available from sustainable forest management and reforestation or planted forests.

7.1 **Background**

The most-forested nations in the Pacific region are the Melanesian countries, with forest covering more than 50 percent of the total area. The New Guinea Island is the third-largest tropical forested land in the world, following the Amazon and Congo Basins (Babon & Gowae, 2013). In 2009, the Papua New Guinea Forest Authority (PNGFA) estimated that forests covered 63 % of PNG, or 46 million hectares (PNGFA, 2012). By 2015, the country had an estimated forest cover of between 29 and 33 million hectares (FAO, 2015). Plantations are estimated to cover between 62,000 and 86,000 hectares (FAO, 2016; PNGFA, 2012), with many being of poor quality. About eighty percent of the population live in rural areas and depend heavily on their forests for fuelwood, housing timbers, a variety of non-wood forest products, and in some areas are also the location of swidden agriculture. Women play a key role in obtaining and managing these household resources, especially in relation to agriculture (Allen, 2009).

Forest loss is a crucial issue for the Pacific Island countries. Particularly, PNG and the Solomon Islands, which have lost the most forest among the Melanesian group, resulting from land clearing for cultivation and encroachment following forest harvesting (FAO, 2011). Loss of primary forests in PNG showed sharpest decline in all of the Asia-Pacific region, from 31.3 million hectares in 1990 to 17.6 million hectares in 2015 (FAO, 2019a). Many challenges have put pressure on forest management and conservation of the small island countries in the Pacific resulting from being highly vulnerable to natural disasters, economic constraints of geographical isolation, institutional arrangements, land tenure systems, and lack of integrated land use planning (Wilkie et al., 2002).

7.2 **Community Forestry**

The importance of community forestry as outlined in The PNG Medium Term Development Plan underlines that the “forestry sector continues to contribute immensely to the national economy, as well as improving the livelihoods of the rural poor”. In order to achieve this goal, one of the nine sector strategies is to “Promote community forestry activities with the view of empowering rural communities and alleviating poverty.”

7.2.1 Community Eco-forestry

The management of natural forests is primarily based on an industrial model (Hurahura, 2012) with community forestry being practiced under a few names in PNG e.g. eco-forestry, small-scale forestry and community-based forestry enterprise (Nau-Buga, 2010). Eco-forestry was advocated and supported by a number of NGOs and community groups in the past (Bun & Baput, 2006; Rogers, 2010) and has been broadly supported by the PNGFA which prepared a draft white paper on ecoforestry policy in 2004 (PNGFA, 2004). The PNGFA has not revised the draft white paper since 2004 and the existing forest and legislative policy framework continues to impose complex, technically challenging and expensive requirements for landowners to harvest timber on a small-scale for commercial use.

The PNG government endorsed the Eco-Forestry policy (under the National Forest Policy) to promote small-scale, community-based timber harvesting (Bird et al., 2007b; Bun and Baput, 2006) and to enhance landowners’ participation and wise use of forest resources (Hurahura, 2012). They also initiated the **‘***Forest Management Agreement’* (FMA), as a mechanism for customary landowners to transfer forest management rights to the State (Hurahura, 2012), and to secure commitment of the landowners regarding forest management practices (Blaser et al., 2011). This very fact takes away the idea of collective action and decision making on the part of the landowners. Some community-based forestry cases were developed, for example, in Madang, where the Madang Forest Resource Owners Association (MFROA) was formed by the customary landowners in 1998 with assistance from the Foundation for People and Community Development Inc. (FPCD) to operate their timber enterprise (Bun & Baput, 2006). This form of community forestry could only operate if it had subsidies provided by the NGOs and donors. Once these subsidies were withdrawn, the system failed. Scudder et al. (2018) outlined the reasons for the failure of eco-forestry as a small-scale natural forest management model in PNG, which in its current form cannot be successful without heavy subsidies. Hence, it is not surprising that there are currently no viable ‘eco-forestry’ operations in PNG.

7.2.2 Community-based Forestry

Given that most land in Papua New Guinea in under clan ownership, the first plantations that were established in the 1960s were on land that was acquired from landowners by the Department of Forests, under the colonial government and before the PNG constitution was applicable (in 1975, with Independence). The initial plantings involved native species such as *Eucalyptus deglupta*, *Araucaria cunninghamiana* and *A. hunsteinii* as well as exotic species such as *Tectona grandis*, and *Pinus* spp. By 1970, the area of plantations covered 11,300 ha (Lamb, 1990). The plantation program was provincially based and involved provision of tree seedlings from well managed centralised nurseries for government funded plantings to villages accompanied by extension advice and the necessary skills for growing trees on the small and sometimes large areas of both clan land and government owned land. By the mid-1980s, the main species planted were *Eucalyptus, Acacia, Araucaria* and *Pinus* (Bird et al., 2007a), with *Pinus caribaea* and *P. kesiya* the dominant species planted in the *Imperata cylindrica* and *Themeda australis* dominated grasslands in the Markham Valley, west of Lae. Reforestation became part of the National Forest Policy in 1991, designed to encourage commercial timber enterprises and landowner groups to establish plantations (Srivastava, 1992).

In 2003 the parliament endorsed the National Reforestation Policy (Blaser et al., 2011), with the expectation of increasing the area of forest plantations and improving silvicultural management of the selectively harvested natural forests – referred to ,as *'reforestation naturally'* (PNGFA, 2009). Since 1990, PNGFA has taken a levy from the plantation operators (Bird et al., 2007a). Although the PNGFA has reduced funding and resources for supporting forest plantings on clan land and government owned land, the current estimated area of planted forest is about 60,000 ha with little knowledge of the standing stock or volume (Bird et al., 2007b).

Plantation forestry is also recognised as being important to "Develop forest plantations to meet the impact of climate change and to meet future timber demand for both domestic and international markets". In order to facilitate the expansion of the plantation estate, the PNGFA has recently implemented a new program called '*Painim Graun, Plannim Diwai*' (search for land and plant trees) which has plans, but no operational mechanisms to expand the plantation estate in each Province by at least 1,000 ha per annum. However, what functions now in PNG in relation to plantation development is either based on private forestry and semi government enterprises operating on government land or under a 'lease arrangement' with clans for the timber rights, with other plantings based on families operating on quite small areas of clan land. An example of the lease arrangements is PNG Biomass which operates in the Markham Valley, west of Lae.

7.3 **Possibilities and challenges of 'community forestry' in PNG**

In the words of Dr Bob Fisher who has studied communities involved in forestry in PNG for a number of years, explained the following in relation to tree planting and communities (Fisher, personal communication, March 30, 2020):

- Clan members often reside off site and not in the village and can be living with other clans who also don't necessarily live on clan land
- Farming and forestry plantings/ agroforestry are undertaken at the household level or family level as clans are not economic enterprises, but make decisions on land use
- Decision-making by clans is a negotiated and informal process as there are no 'chiefs' and leaders gain authority by prestige, not by birth rights or elections
- Decisions by families to plant extensive areas of trees are often unrealistic, which makes up-scaling problematical for government planning and meeting area-based targets

- There are often no fixed planting targets, with plantings often tending to be in a mosaic pattern and species dependent to some extent on availability of genetic resources
- Clans and families have decision-making power that includes the power to decide to accept or reject programs, thus the potential for making planning reforestation activities an extended process
- Any extension activities or negotiations need to be slow and adaptive, which often is in conflict with projects which are on three-year funding cycles.

7.3.1 Policy development

Since its inception, the PNGFA has promoted sustainable forest management as a key mechanism of it forest policies and legal frameworks in order to sustain the forest with a focus on industrial scale operations in both natural forests and in plantations (PNGFA, 2009). There are also some NGOs working on the ground to enhance SFM practices of rural and small scale forest operators in natural forests. However, there are a number of disincentives and gaps in policy implementation with little funding and resources allocated for small scale community-based forestry in natural forests (Blaser et al., 2011). Holzknecht (2017) described a lack of consistency between higher-level statements, policies, strategies and on-the-ground action. PNGFA is the designated government authority for forest management, so management has been top-down and has diminished resource management of local people because, it is not been conducted in consultation with community and without community collective action.

There is no specific policy on community-based forest management (Baynes et al., 2017) where collective decision making and forest land is managed by local communities or clans. Nonetheless, the development of policies and legal frameworks and the Constitution emphasizes the wise use of natural resources and environment as well as enhanced economic development based on small-scale activity (Bird et al., 2007b).

Some policies were developed under the National Forest Policy, for example, Reforestation Policy and Eco-forestry Policy (PNGFA, 2009), neither of which have or had substantial funding from PNGFA. Key mechanisms promoted in the Forestry Act 1991 are the Forest Management Agreement (FMA), Timber Authority (TA), and Forest Clearing Authority (FCA), all of which are designed to enhance and monitor large scale timber harvesting and at the same time, do little to support small scale forest operations (Blaser et al., 2011).

Local landowners and their community benefit little from the current forestry legal framework. Forest management policies over the past 20 years have focused on industrial scale forest harvesting and often the associated private sector forestry plantation companies. Based on results seen in communities, there has been a shift away from support for local community needs. Forestry laws and regulations have excluded local people from forestry development (Bun, 2012). Landowners' participation and decision-making are limited in the process of timber utilization and harvesting (Bird et al., 2007b) as landowners are not always fully consulted or have a clear understanding about the lease agreements that have been signed with the logging companies (Bun, 2012).

Forestry laws have also become a constraint for small scale community forestry operations, due to a long and costly process to gain a Timber Authority (TA) currently required in most situations (Bun, 2012; Scudder et al., 2018). In addition, small scale operators have difficulty meeting the regulatory conditions of timber harvesting currently designed for large scale commercial harvesting operations harvesting large timber volumes (Bun, 2012). Concerns have emerged related to complicated issues of lands and forest ownership, and the low capacity of local people to engage in timber production and management (Yosi et al., 2011) along with the current regulations which also enhance the powers of the PNGFA to continually hold and control customary management decisions on clan land (Holzknecht, 2017).

7.3.2 Forest governance

Governance failings in PNG's forestry sector has been a concern for some time (Bird et al., 2007b). The 'Barnett Report' revealed the imbalance of power between national level and provincial level forestry and the high level of corruption within the forest industry (Barnett, T. E and Asia-Pacific Action Group, 1990). The government responded to these findings by revising the forest policy through a consultative process (Bird et al., 2007b). Despite the government having undertaken many efforts and designed mechanisms for enhancing local participation for a development of their forest resources (Blaser et al., 2011), forestry development processes in PNG are still top-down (Bun, 2002). Enforcement of forest laws and regulations has been reduced in recent times, particularly in the logging industry (Yasmi et al., 2010). Part of the explanation for these failings can be found in the Transparency International report 'Corruption Perceptions Index' in 2018 which ranked PNG 138 out of 180 countries (Transparency International, 2018). The report documented high risk corruption in the forestry sector from the enforcement of legislation of forestry law, the poor management and capacity and resultant outcomes of the 'Incorporated Landowner Group: ILG'[2], and the awarding of timber permits and authorities (TAs), monitoring of the logging operations and environment regulations (Avosa, 2011). The other part of the explanation is that regulatory authorities are under-funded and under-resourced to carry out their roles and responsibilities as forest managers (FAO, 2011).

Local participation is the key to sound forest governance. However, communities in PNG have had little involvement in the development of forest policies, laws and their implementation (Holznecht, 2017). Many customary landowners have not been recognized and their rights over their clan-owned forests are vulnerable to exploitation (Babon et al., 2014). Most benefits from logging have often gone to political elites rather than communities (Laurance et al., 2011; FAO, 2011; Babon et al., 2014). Hence, any development of community forestry depends on improvements to forest governance. Decentralizing forest governance and management, perhaps to the provinces, which was the case prior to the formation of the PNGFA, would promote community forestry on the ground (Brancalion et al., 2016; Dawson et al., 2017).

7.3.3 Land resources and customary rights

The system of land tenure in PNG is based on customary ownership by traditional clan entities, with more than 85 % of forest areas owned by local people (FAO, 2011). Despite strong legal customary tenure rights, which are not subject to state control, there has been little attempt to identify ways for top-down legal controls to meet customary land tenure and use systems (Holznecht, 2017). Moreover, current legislation requires the government to manage forests through FMAs including the rights to manage harvesting operations and to obtain royalty payments (Gilmour, 2016), thus removing the actual landowners from the management of their resource. Large scale timber companies are granted concessions from the PNGFA, and then gain legal timber harvesting rights. Even though local people receive royalties from timber harvested from their lands, the amount they receive is small in relation to the market value of the logs (Fisher et al., 2014). Scudder et al. (2019) found that the landowners obtain only 6.1% of the market value of the logs harvested. The government and the industrial logging companies gained most, i.e. average of 42.3% and 51.6%, of the price of the logs sold respectively.

To integrate customary landowners in land resource mobilization, the PNG government enacted the *'Incorporated Landowner Group (ILG)'* to manage land resources for economic development. ILG is a way to recognise the resource rights of the customary social groups, which they hold and manage on behalf of their group members (Holznecht, 2017). In reality (but perhaps not in theory), ILG tend to be used as a short cut by 'developers' to gain landowner consent for resource exploitation, which

[2] An ILG is a legal framework on land right management, under the Land Groups Incorporation Act 1974 (Bird et al., 2007b; Blaser et al., 2011)

can result in failure due to the lack of capacity of the government and political will to implement this mechanism (Tararia & Ogle, 2010). One of the first problems with ILGs involves PNG law, as there is nowhere in PNG law where 'landowner' is defined "*and the issue of 'landownership' as such, is largely an artifact of the recent mineral exploitation in PNG*" (Filer, 1997). In the context of development, Filer has suggested "*the question of whether 'clans' exist as 'landowners' in the fabric of national identity is the question of how 'clans' have actually become groups of landowners claiming compensation from development of their own resources*". The concept of landowner goes back to the wording in the explanatory addenda to the *LGIA* originally developed for the petroleum industry.

Even if ILGs are used, the rights of the customary landowners are often ignored because of a lack of information from the operators who are theoretically in partnership with them (Avosa, 2011). Under these limitations, it is suggested that local people have strong de jure rights but little de facto rights (Babon et al., 2014).

Land disputes are common in PNG and land resources have traditionally been a cause of disputes in society (Banks, 2008; Westermark, 1997). The government endorsed the Land Disputes Settlement Act 1975 by creating three structures for dealing with land conflicts (i.e. from local to provincial, to national levels). However, this system has not operated effectively (Oliver & Fingleton, 2008), especially when economic opportunities introduced by external organizations brought changes to land values in rural areas, resulting in a rise in conflicts which have continued from past decades till recently (Allen & Monson, 2014; Westermark, 1997). Because community forestry may provide benefits from forests to local users and communities, land values may increase as a result. Hence, forest development in PNG may need to consider cultural systems and customary land right patterns at an early stage in order to avoid and mitigate intra-and inter-clan conflict. This may be even more important with the partial log export ban and the potential reduction in industrial logging and the resultant emphasis on local processing from clan owned resources.

7.3.4 Socio-cultural considerations

Forestry in PNG as far back as the 1970s has encountered what some have described as sociological rather than ecological problems, complicated by traditional land tenure (Lamb, 1977). Land is owned by clans and this land has been passed down from generation to generation (Bun, 2012). The concept of clan land ownership influences an individual's rights over the land because, for example, planting trees for commercial purposes needs approval from clan leaders (Fisher et al., 2014). Hence, the motivation of PNG's farmers to plant trees in some locations maybe influenced by uncertainties inherent in their customary land tenure system (Baynes et al., 2017). However, prior to the formation of the PNGFA, the forestry service was more provincial based and had resources and budgets to support local tree planting on clan land with centralised nurseries producing high quality seedlings. In areas near Lae, the results of this extension service can be seen today, with many families currently harvesting the trees that they were encouraged to plant many years ago. The income from the sale of the logs goes to the families who planted the trees.

The participation of women in land management decisions can be limited, but is influenced by traditional customs and norms in patrilineal societies that predominate (Baynes et al., 2019). Therefore, the complexities of political and socio-cultural aspects have influenced the success of resource management by communities and influences such activities as tree planting and this is likely to continue.

7.3.5 Current developments in community-based forestry initiatives

In general, community forestry (community eco-forestry) in relation to natural forests in PNG was initially supported by NGOs. This support has greatly reduced in recent years. Scudder et al. (2018) found that eco-forestry had failed due to aspects of financial unviability, the poor quality and quantity of lumber products, and an inability to reach FSC certification standards. Furthermore, the capacity of local people to participate was limited. Bun (2012) observed that with the current situation in PNG, many local communities, or the clan leadership are more willing to sit back and wait for royalties and payments from forest management and harvesting, executed by the forest authority. In this situation, they may become less self-reliant on managing forests for their livelihood development.

In terms of community forestry, the relatively new program called '*Painim Graun, Plannim Diwai*' (search for land and plant trees) has plans to expand the plantation estate in each Province by at least 1000 ha per annum. However, these plans for plantation development are either based on private forestry and semi government enterprises operating on government land or under a 'lease arrangement' with clans for the timber rights, with other plantings based on families operating on quite small areas of clan land. This policy has few regulations as to how this policy will be implemented and may be more focused on smallholders and large enterprises planting on government land or on concessions or private lands. While tree planting in some parts of PNG such as in New Britain is very well established, in places such as the Markham–Ramu valley community or family tree plantings have not been as popular. Baynes et al. (2017) suggested that this may be due to social, political and cultural constraints, where collective action by communities may not be a realistic outcome for community-based reforestation or FLR but that family-based agroforestry, as has been demonstrated in a number of communities may be possible.

8. Conclusion

This study has reviewed the progress of community-based forestry in the Asia-Pacific and outlined the different meanings of the term as used by different stakeholders, along with the approaches and lessons of those approaches related to planning, execution and the different perspectives that define success.

Many of the large-scale reforestation activities in the Asia Pacific region that have reforested hundreds of thousands of hectares involving communities have been funded and managed by central governments, with the communities supplying the labour for tree planting. A close look at the policies in many countries relating to community-based forestry pay little attention to the tenure rights, which are usually vested in the government and provide little in the way of supporting collective action or smallholder forestry on a landscape scale. This approach has never-the-less been seen by many as being successful as trees have been established on degraded forest land.

In most countries in Asia Pacific, even in Melanesia where the government does not own most of the land or forests, the capability of communities to actually have effective management power to manage their community land limits their scope to successfully undertake community-based reforestation or FLR to combat the impacts of deforestation forest degradation and poverty.

The terms community-based forestry, or community forestry are generic and cover many activities involving reforestation or the different forms of "FLR". In Asia Pacific, much of the scientific literature, as well as the different institutions' reports and government policies have titles including the words, 'FLR' or 'community-based forest management', but what is often described in the documents is reforestation, managed by central or local governments, with communities mainly involved to plant the seedlings. There are few examples apart from perhaps Nepal and the smallholders in parts of Indonesia which can, under current definitions be considered as community forestry, where collective action by communities is undertaken or by individuals, for managing forests on the own land.

There seems to be a lack of shared understanding or common interpretation of the generic term 'community forestry', which also contributes to the confusion and lack of real action on the ground.

Arriving at a common or shared understanding of the term is important as many institutions involved in policy making or implementation have as their goal which has gained wide recognition, 'to improve rural livelihoods and reforest and protect existing forests'. Community involvement in forest management has also become an important forest conservation strategy for conservationists, ecologists, scientists, governments, and non-government agencies who are working on forest management, so a shared understanding of the meaning of terms in different countries and cultures is important for the success of these programs.

In parts of Asia Pacific, south Asia in particular, show more cooperation and involvement of women in decision-making of forest management, although some community forestry programs have excluded women because of gender behavioural norms and social customs.

This study has looked at community forestry in the Pacific where there are currently no specific policies regarding community-based forestry as it relates to collective action on the part of communities over management of their land. In many of the Pacific countries, tree planting is not practiced widely, and the potential and challenges to expand from small, 'haphazard' family based plantings of a few trees on clan land allocated to them for this purpose, to scaling this to many families at landscape level may not be viable under current economic and social conditions. In this situation, families may become less self-reliant on trees for part of their livelihood and due to the fact that many communities have limited possibilities for collective action, family-based agroforestry may be possible and a potential mechanism for scaling-up tree planting to a landscape scale, with many individual families involved from numerous clans.

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10. Annex 1: The cases of the community-based landscape scale restoration programs/projects

Table 1: Reviews of the example cases of the community-based landscape scale restoration

Title	Reference
Cases from the peer-review publications	
Economic Aspects of Community-Based Forest Management Program as a Strategy for Forest Landscape Restoration in the Philippines	(Camacho et al., 2007)
Realities of Forest Landscape Restoration: The Case of Barobbob Watershed, Philippines	(Combalicer et al.,2007)
Forest Landscape Restoration in the Drylands of Latin America	(Newton et al.,2012)
Integrated livelihoods and landscape approach for smallholders in Northern Thailand	(Cadena et al.,2014)
Restoring forest landscapes: Important lessons learnt	(Mansourian & Vallauri,2014)
Governing Forest Landscape Restoration: Cases from Indonesia	(van Oosten et al.,2014)
Governance of restoration and institutions: Working with Ghana's Community Resource Management Areas	(Baruah et al.,2016)
Novel governance for forest landscape restoration in Fandriana Marolambo, Madagascar	(Mansourian et al.,2016)
Nadi Bachao Samriddhi Lao – A forest landscape restoration initiative in Harda district, Madhya Pradesh, India	(Saigal et al.,2016)
Against all policies: Landscape level forest restoration in Tanzania	(Sungusia & Lund,2016)
Institutional innovation and forest landscape restoration in China: Multi-scale cross-sector networking, household fiscal modernization and tenure reform	(Zhang & Putzel,2016)
Change in land use and ecosystem services delivery from community-based forest landscape restoration in the Phewa Lake watershed, Nepal	(Paudyal et al.,2017)
Implementing Forest Landscape Restoration in Ethiopia	(Pistorius et al.,2017)
Cases from the grey literature	
Forest Landscape Restoration: Building Assets for People and Nature - Experience from East Africa	(Barrow et al.,2002)
Investing in trees and landscape restoration in Africa: What, where, and how	(Dewees et al.,2011)
Principles and Practice of Forest Landscape Restoration: Case studies from the drylands of Latin America	(Newton & Tejedor,2011)
Improving ecosystem functionality and livelihood: Experiences in forest landscape restoration and management	(Barrow et al.,2012)
Lessons learnt from WWF's Worldwide field initiatives aiming at restoring forest landscapes	(Mansourian & Vallauri,2012)
Forest land restoration enhances food security in Sahelian landscapes	(Djenontin et al.,2015)
Enhancing food security through forest landscape restoration: Lessons from Burkina Faso, Brazil, Guatemala, Viet Nam, Ghana, Ethiopia and Philippines	(Kumar, C., Begeladze, S., Calmon, M. and Saint-Laurent, C.,2015)

Title	Reference
Mainstreaming forest landscape restoration and biodiversity conservation: case studies from the international model forest network	(International Model Forest Network, 2016)
Lessons Learnt from 17 Years of Restoration in New Caledonia's Dry Tropical Forest	(Mansourian et al.,2018a)
Lessons Learnt from 13 Years of Restoration in a Moist Tropical Forest: The Fandriana-Marolambo Landscape in Madagascar	(Mansourian et al.,2018b)

Table 2: Key activities for engaging local people in community-based landscape scale restoration initiative

Example cases of community-based landscape scale restoration	Nursery/ Seedling production	Using indigenous species	Plantation, mix-species	Silviculture techniques	Biodiversity conservation	Agroforestry farms	Improve cropping system	Participatory land use plan	Establish community forests	Establish protection area	Forest mgmt. plan/ rules	Soil conservation	Water resource mgmt.	Forest fire management	Timber & NTFPs mgmt.	Reduce fuelwood uses	Securing tenure / rights	Alternative livelihoods	Training/Awareness raisings	Local institutional arrangement	Multi-stakeholder platform
Barobbob Watershed, Philippines (Combalicer et al., 2007)	x	x	x			x	x	x			x	x					x	x	x	x	x
Quirino Province, Philippines (Camacho et al., 2007)	x					x									x			x		x	
Kawayanon community, Biliran Province, Philippines (Gregorio et al., 2015a)	x	x	x			x		x		x				x			x	x	x	x	
Doi Mae Salong, Thailand (Barrow et al., 2012; Cadena et al., 2014)	x	x	x		x	x	x	x				x			x		x	x	x	x	x
Miyun watershedp, China (Barrow et al., 2012)		x	x	x	x			x		x	x		x	x	x	x	x	x	x		x
Pathoumphoune District, Lao PDR (Barrow et al., 2012)					x			x			x		x		x			x	x	x	x
Central Annamites landscape in Lao PDR and Vietnam (Mansourian & Vallauri, 2012b)		x	x								x				x				x		x
Kinabatangan river in Borneo, Malaysia (Mansourian & Vallauri, 2012b)	x	x	x		x					x	x							x	x		x

Example cases of community-based landscape scale restoration	Nursery/ Seedling production	Using indigenous species	Plantation, mix-species	Silviculture techniques	Biodiversity conservation	Agroforestry farms	Improve cropping system	Participatory land use plan	Establish community forests	Establish protection area	Forest mgmt. plan/ rules	Soil conservation	Water resource mgmt.	Forest fire management	Timber & NTFPs mgmt.	Reduce fuelwood uses	Securing tenure / rights	Alternative livelihoods	Training/Awareness raisings	Local institutional arrangement	Multi-stakeholder platform
Halimun-Salak National Park, West Java, Indonesia (van Oosten et al., 2014)	x		x			x		x													x
East Kutai District, East Kalimantan, Indonesia (van Oosten et al., 2014)			x					x											x		
Sungai Wain, Balikpapan City, East Kalimantan, Indonesia (van Oosten et al., 2014)			x					x			x				x			x			x
Harda district, Madhya Pradesh, India (Saigal et al.,2016)	x		x							x		x	x						x	x	x
Phewa lake watershed, Nepal (Paudyal et al.,2017)			x		x	x	x	x	x	x	x	x	x		x			x	x	x	

Scientific Impacts

Development assistance to reforest the grasslands of Papua New Guinea is best directed at families rather than clans. Extensive investment is required in developing social and human capital.

Capacity Impacts

Species research trials and seedling production training in nurseries have been beneficial to the partner organisations as well as to the communities who have little knowledge on how to produce high quality seedlings with the limited infrastructure and materials they have available.

Economic Impacts

The existing constraints to the Timber Authority harvest permit have been identified and discussed with PNGFA government officials along with forest policy revisions that can assist forest communities with accessing formal timber markets to improve livelihoods.

Social Impacts

Research on timber royalties has been compared to revenues received from informal market small scale producers, thus providing a better understanding of landowner income in relation to the benefits of the other parts of the supply chain.

Environmental Impacts

Current small-holder timber harvests undertaken in natural forests is focused on the most profitable species and this has led to high-grading of the forests harvested by communities, even though the volumes harvested are small.

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Australian Centre for International Agricultural Research

Enabling Community Forestry In Papua New Guinea

ACIAR Project FST-2016-153

ACIAR

Project Activities

The project aims to improve rural livelihoods through family focused reforestation and improved value returned to landowners through small-scale timber harvests.

A social science training workshop was held at Ramu in January, 2018. Forest extension activities in the Ramu Markham Valley have been carried out in partnership with the project partner Ramu Agri-Industries Ltd (RAIL). Training has focused on the establishment of seedling nurseries in the villages of Atzunas and Marawassa.

Seed collection assesment

Nursery soil preparation training

Completed polybags

A multi-species, multi-purpose agroforestry demonstration planting at Umi, adjacent to Ramu, has been planted and is growing well. A key feature of the demonstration planting is *Theobroma cacao,* which is recieving increased interest from landowners due to cocoa markets expanding into the Ramu Markham Valley. The selected shade trees for the cocoa trees include *Eucalyptus pellita*, and *Gliricidia sepium.* The selected food crops for the Umi planting include sweet potato, cassava, bananas, corn, and beans.

A bio-economic model is being developed to identify the potential financial returns on labour that rural landowners can receive from these agroforestry activities.

Umi planting demonstration site

Portable sawmill training

In Papua New Guinea, there is a large informal timber market made up of small-scale forestry participants using portable sawmills. A case study has been conducted on this informal market to identify the reasons people choose to participate, as well as to offer policy revision options that may help to increase formal timber market participation.

A financial analysis on the portable sawmills has been performed to identify opportunities for improving the profitability of small-scale forestry operations and to improve the financial returns received by rural forest landowners.

A forest management plan template and reduced-impact-logging guidelines have been developed that are appropriate to the scale and complexity of rural forest landowners, to improve future small-scale forest management.

Anthropogenic fires in the Ramu-Markham Valley: Underlying causes and motivations.[1]

Nathan Wampe, Robert Fisher, Grahame Applegate and Jack Baynes

Anthropogenic fires present a continuous challenge to landscape management in the Ramu Markham Valley (RMV) in Papua New Guinea. Aided by favourable climatic and weather conditions, topography and fuel availability these fires have proven to be detrimental to areas affected. The fires affect commercial plantation crops (oil palm and sugar), restored forests and locally established agricultural gardens. Strategies to reduce fire damage and incidence will depend on better understanding of the range of causes and, in the case of deliberately lit fires, understanding of motivations. Popular explanations of fire lighting behaviour tend to make simplistic assumptions about cultural practices, including the idea that "people just like lighting fires". Common cultural practice in the RMV see fires being lit for hunting, to prepare land for gardens and as a result of conflicts. It is essential to understand and differentiate between fires that are lit due to cultural practices and those that are lit to target the gardens of individuals or commercial crops. This paper reports on data on recorded fire events in and around Ramu Township and the area of operations of Ramu-Agricultural Industries Limited (RAIL). Evidence on the causes of these fires is presented and analysed in order to establish a typology of causes and motivations of anthropogenic fire in the RMV.

Keywords: *Anthropogenic fires, Landscape Management, Causes, Motivations*

[1] This report is a revised and updated version of a paper presented by Nathan Wampe at the International Conference Forest and Landscape Restoration: Making it happen. 25-27 February, 2019, New World Hotel, Makati (Manila). It is intended that the report will be further developed for publication after the formal end of the project.

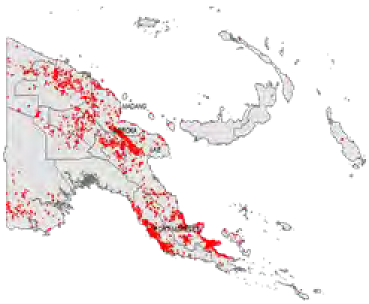
Introduction

The Ramu-Markham valley runs between two major mountain ranges in northern Papua New Guinea. The Ramu River runs to enter the sea in the north-west and the Markham River joins the sea in the south-east of the valley. The watersheds of the two rivers are separated by relatively low boundaries, making the RMV effectively a single valley. The floor of the central RMV consists primarily of grasslands, with forests on the surrounding mountain slopes.

Large portions of the grasslands, especially in the central portions of the valley, are anthropogenic, possibly dating back for up to three thousand years. Anthropogenic fire continues to be a major factor in the valley and aided by favourable climate and weather conditions has proved to be a problem for some agricultural and forestry activities and is a major concern for commercial operations and reforestation efforts. In the area around Ramu, near the juncture of the upper Markham and Upper Ramu valleys, Ramu Agri-Industries Limited (RAIL) runs a large business involving palm oil and sugar plantations. RAIL also works on the restoration of forests in riverine areas in response to its legal requirements under environmental regulations and its licences. The forest restoration activities include a component carried out in collaboration with a project supported by the Australian Centre of International Agricultural Research (ACIAR)[2]. The project focuses on family and small group agroforestry to combine tree planting and agriculture.

Fires are particularly common in the RMV (Figure 1). The extent of anthropogenic fires in the area is a major problem for RAIL's commercial plantations and threatens commercial plantation crops (oil palm and sugar), restored forests and locally established agricultural gardens. In order to reduce or manage this threat, strategies to reduce fire incidence and damage need to be developed. However, developing such strategies is impeded by a lack of nuanced understanding of the specific causes of fires and motives of people who light them.

Figure 1*: Map demonstrating the high level of fire in the RMV compared to other areas in PNG. Source: MODIS thermal image, downloaded from NASA website, July 2018*



While there is some understanding of causes and motivations, there has been little systematic analysis of these issues. It is fair to say that much of the current understanding consists of anecdotal discussion of individual fires. There is also a popular view, rarely, if ever,

[2] The project, managed by the University of the Sunshine Coast, is titled "Enabling Community Forestry in Papua New Guinea". It is the latest of a number of ACIAR projects which have worked with RAIL in the Ramu area.

expressed explicitly in the literature, that fire lighting often occurs just because “people just like lighting fires”. In other words fire lighting is just a culturally valued habit.

The aim of this paperis to explore fire lighting beyond such simplistic explanations and assumptions. It is essential to understand and differentiate between fires that are lit for cultural reasons, including land management and those that are lit to target the gardens of individuals or commercial crops. For this reason the paper attempts to develop a typology of the types of causes of anthropogenic fires in the RMV. The paper is based on the views of informants from rural communities and analysis of data on recorded fire events in and around Ramu Township and the area of operations of RAIL. Evidence on the causes of these fires is presented and analysed in order to establish a tentative typology of causes and motivations of anthropogenic fire in the RMV.

The paper does not present the results of detailed research. In the absence of previous systematic study, it is intended to be preliminary and exploratory attempt to explore what is known, in order to inform future efforts at FLR and future research.

Methods

The data used for this exploratory study comes from two sources. The first is from data available from RAIL. This consists of incident reports on fires collected by RAIL, supported by interviews with RAIL staff with responsibility for dealing with fires. The second is from informal interviews with key informants from communities in villages near Ramu and the RAIL operations. In addition to the sources of data reported in this report, a very brief follow up round of six interviews and small group disucssion were carried out with villagers in June 2020.

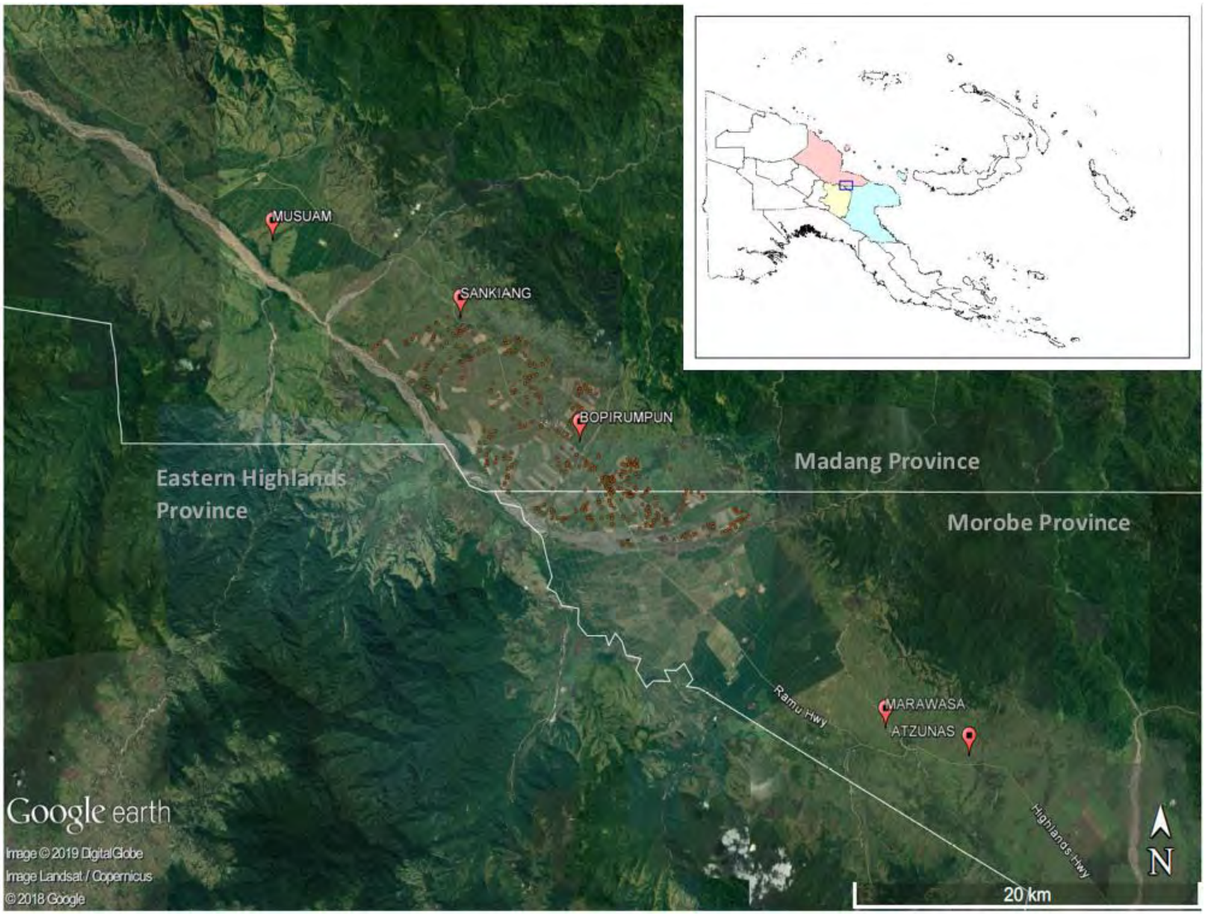
RAIL Fire incident reports are prepared on fires identified as fire hotspots based on satellite imagery and by reports from individuals. These reports principally specify the location of the fire in RAIL Operations, the area affected and the extent of the damage in terms of crop or RAIL property loss. The reports, following further investigations, sometimes identify the cause of a fire and the motivation for lighting it.

Four RAIL staff were interviewed. Each informant was purposely selected from a department/section of RAIL relevant to dealing with fires. The informants were from the Oil Palm Department, Agriculture (Sugar) Department, Sustainability Department and the Asset Protection Division (APD). The sample size is small but purposive being that the informants held senior positions in their respective operations.

The topics of interviews focused on identifying which RAIL operational areas were affected by fires and whether the fires that occurred were natural or anthropogenic. If the latter, then for what purpose were they lit?

A total of fifteen villagers were interviewed. These came from six villages namely Musuam, Sankiang, Bopirumpun, Sausi in Madang Province and Marawasa and Atzunas in Morobe province (see Figure 2). They were selected purposively as key informants on the basis of suggestions by RAIL staff (snowball sampling). Consistent with the practicalities involved in an exploratory/scoping study, the sample was purposive, not random.

Figure 2: *Location map indicating five villages from which community informants were interviewed. The settled area is the RAIL factory area and Ramu township.*



The topics for the local interviews were based on understanding the fundamental context of anthropogenic fires in the local setting. This is concerned specifically with identifying the causes and motivations associated with anthropogenic fires. The topic required the informants to produce their general opinions on why they think these fires are lit. Examples of local fire lighting scenarios that occurred in the local setting were sought for illustration purposes.

RAIL data and interviews with staff

This section of the paper reports on information provided by RAIL records and interviews with RAIL staff.

Figure 3 analyses fire incidents showing fire incidents that occurred in different RAIL operational areas (Sugar, Oil Palm, Forestry Plots and others). This information is based on the Official Fire Register from RAIL dated 1 April 2016 to 16 October 2018. A total of 1576 fire incidents were recorded during that time. Of these, 1412 Fire incidents occurred in the Sugar operational areas, 129 in Oil Palm Blocks, 22 in forestry plots and 12 were other fires (rubbish burning in industrial zone, machinery fires etc).

Figure 3: *Pie chart indicating percentage of fires within different RAIL operational areas from April 2016-16 October 2018*

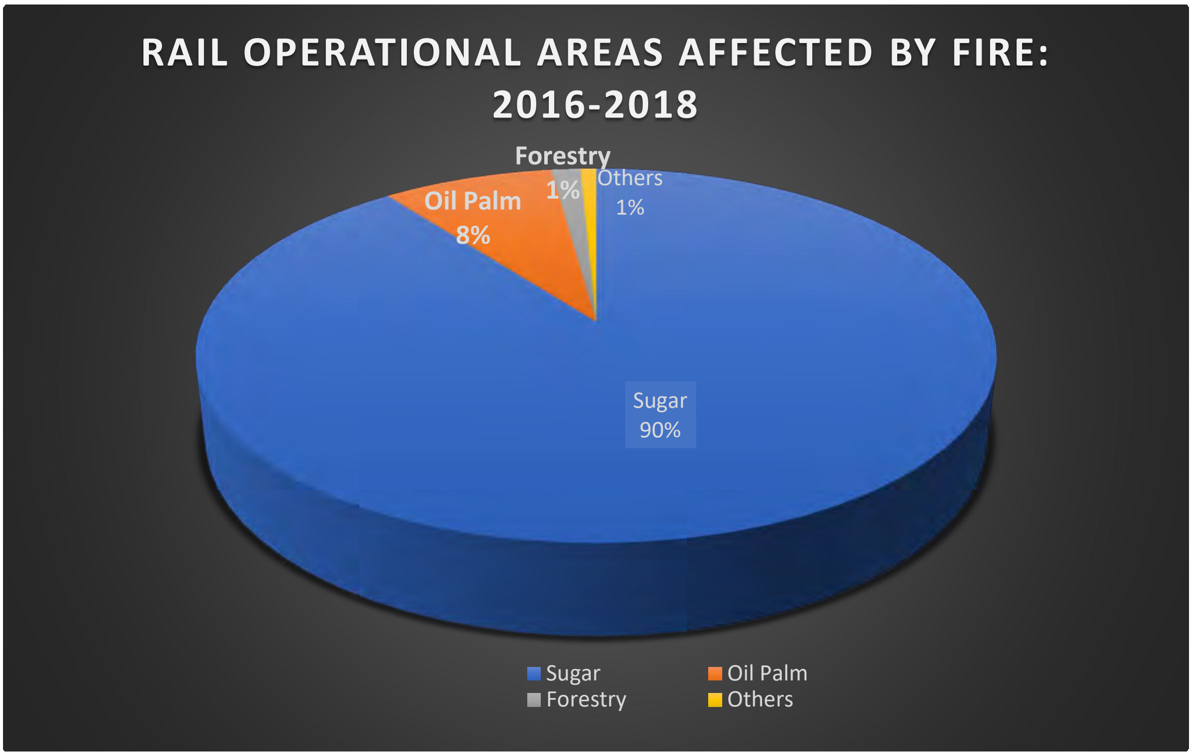


Table 1 gives eight examples of specific fire incidents that occurred in RAIL Operational Areas. These examples are sourced from the RAIL Fire Register dated 1 April 2016- 16 October 2018, which, as mentioned above refers to a total of 1576 fire incidents reported. The selected incidents show the causes and motivations behind the fires lit. Additional information on the oil palm fire incident reports listed in the table were sourced from fire hotspot notifications (by satellite imagery). It is important to note not all fire incident reports give details about who lit the fire and why why it was lit. Investigations mostly find that the reasons are unknown.

Table 1: *Examples of fire incidents based on Fire Incident Reports*

Incident Description	Source of Fire	Causes	Motivation
Fire in oil palm block DN901 on 26/08/17. Approximately 0.5 hectares affected, palm fronds burnt though minimal damages. Fire	Fire lit nearby cattle field and jumped into the block due to strong winds	Locals started fire to control grassland in cattle field.	Accidental spread of fire lit for NRM management purposes.

extinguished by plantation team			
Fire in Smallholder block on 16/08/2017 approximately 0.5 hectares affected. Fire began at the back of the block. No apparent damages, just minimal.	Fire lit at grassland area behind the block, however wind direction caused fires to jump into smallholder block.	Locals started the fire. Accidental spread	Fire was lit in the kunai grass area at the back of the block to hunt for pigs
Fire in Oil Palm Block. 32 Hectares were burnt. Occurred on 09/07/17. Fire Extinguished by Plantation team	Multiple fires lit within the oil palm blocks.	Locals started fire.	The report identified it as an act of arson. Was deliberately done as the fires were started within the oil palm block. Individuals who started the fire were identified. The apparent motive was not identified and was to be investigated
Fire in 2 Oil Palm Blocks approximately 2 Hectares affected. Fire was extinguished by Plantation Team	Fire lit at nearby gulley and oil palm block boundaries. Fires jumped into the oil palm blocks	Locals started fire	Fires lit along the oil palm block boundary and nearby gully while hunting bandicoots.
Fire in Sugar Field affected 6.8. Fire extinguished by Sugar Fire Response Team	Fire lit in nearby grassland jumped into the sugar field	Locals started fire	Fires lit in nearby grassland specifically by the locals for hunting bandicoots.
Fire in Sugar field on 14/07/16. Approximately 11.0 Hectares burnt.	Fire lit within the sugar field	Evidence suggests the fire was deliberately lit	No apparent motivation
Fire in Forestry Block. Affected Native tree species	Fire started at the boundary of the forestry Block	Evidence suggests fire deliberately lit	The motivation was unknown, but evidence does suggest that the fire was not extinguished after being lit to cook banana.
Fire in sugar field on 17/07/16. Approximately	Fire started at the boundary of the Sugar	Evidence suggests fire deliberately lit	Motivation unknown as per the investigation report

10.4 hectares burnt.	field and jumped into the Field.		

Based on the round of interviews with RAIL employees, it is possible to group fires that affected RAIL according to apparent motivation: that is, whether the fires spread accidentally, whether they were lit deliberately to cause damage or whether they were lit for no apparent reason. See Table 2.

Table 2: *Intentions behind lighting of fires that affected RAIL operations based on interviews with RAIL staff*

Causes of Fires in RAIL Operation	*Specific Motivation*	*Description*
Accidental	Fires lit due to NRM Management	Locals in surrounding villages specifically light fires for NRM Management. When these fires are not managed properly accompanied with suitable conditions (weather, climate, fuel and topography) have caused fires to affect RAIL Operations (Mostly sugar fields sometimes oil palm and forestry blocks).
Deliberate	Due to Conflicts	Fires lit deliberately within RAIL Operations by individuals having disagreements/conflicts with RAIL (Mostly in Sugar fields and some in Oil Palm Blocks, few in Forestry Bocks). Use this as an avenue to show their frustration.
Amusement (other)	Fires lit for amusement	Fires lit with no apparent reason. Aided with suitable weather climatic conditions, topography and fuel availability spread to affect sugar, oil palm and forestry blocks

Accidental

From a general perspective of the RAIL Employees interviewed, fires mostly affect the sugar fields and less often oil palm and forestry blocks. Some fires are classified as deliberately lit but accidentally affect these RAIL operational areas. These fires are initially lit in areas most dominated by grassland for hunting and land preparation for gardening. However, with the presence of strong winds and fuel availability these fires jump onto the nearby sugar fields, oil palm or forestry blocks. There have been cases where locals were caught, however they have stated that these fires were lit without intent to cause harm to RAIL operations and it was the work of nature (wind direction, fuel).

Deliberate

Generally, the informants stated that fires lit in RAIL operational areas are determined to be intentional when the fires are started within the plantations and forestry sites. There have been numerous cases where perpetrators were caught and upon investigations it was found that these fires were lit intentionally out of disagreements with the company for various reasons. There have been cases where radical individuals in a community have led groups of people and have lit fires in the operational area. One such was in an oil palm block.

From the interviews, it was generally noted that fires which were lit for no apparent reason and motivation and just lit for “fun” and amusement may also get out of hand given the suitable conditions in which fires thrive in.

Community interviews

From the informal survey no cases of natural causes of grassland fires in the RMV were reported. Some informants stated specifically that all fires are caused by people Most of the fires lit are lit deliberately for a specific natural resource management (NRM) purpose. These fires sometimes to get out of hand and cause destruction in certain areas. The destruction is aided by conducive climate and weather conditions, availability of fuel and topography. The destruction that is caused is not intentional but is accidental. Other causes of fire are deliberate fires lit intentionally to ruin a certain area or lighting fires for other reasons, such as “having fun”.

NRM Management

Fire is used mainly in RMV villages to remove *Imperata cylindrica* (Kunai Grass) to prepare the land for cultivation. There are two ways to utilize fire in this activity. The Kunai grass is either burnt from its roots up or it is manually removed and placed in huge piles where it is burnt.

Fires are also lit by local people in parts of RMV to facilitate a healthy regrowth of Kunai Grass to allow for it to be harvested and utilized to construct a roof cover for local housing. An informant stated that utilizing Kunai grass for local housing has been a traditional activity. There are areas selected for Kunai grass is harvested for this use. These areas are free from livestock invasion or garden activities.

Lighting of fires in a partially forested area to allow a healthy regeneration of suitable tree species for the purpose of house construction. As stated by an informant from Sausi village a regrowth of suitable tree species for house construction materials is needed. By burning the area it allows the healthy regrowth and eases the workload in terms of site maintenance.

It is a common practice where Kunai grass area is burnt in order to hunt for grassland rats, bandicoots and wild pigs. These are some of the primary protein intake for the locals across RMV. An informant from Bopirumpun village stated that, in the past, burning of grassland was done in specific hunting areas much further from the villages. The areas allowed to be burnt were clearly demarcated with natural markings such as trees, vegetation cover and landform. However, in recent times people are lighting fires according to will in order to hunt.

Conflict

Some fires in the RMV may be lit as a result of conflict. This sprouts from disagreements, vengeance and jealousy. An informant from Musuam Village alleged that there were three cases where his cocoa plot was burnt. He knew it was deliberate because the fire originated from within the plot. He said that the cocoa he was growing had a good yield and he was successfully selling his produce prior to having it destroyed by the three consecutive fires. He attributed the burning of his plot to jealous villagers. This was done during the dry seasons.

Some fires are lit in gardens specifically to destroy the harvest. There was a case where an informant's garden was allegedly destroyed by fire as a result of an argument that stemmed from an incident where his pig invaded another villager's garden and destroyed it. In retaliation the villager deliberately lit fire in the informant's garden destroying what was left for harvest.

Amusement

According to informants, some fires in the villages are lit for no particular reason. This is apparently done for amusement. An informant from Bopirumpun village stated that there was a case in early 2017 where local kids while returning from the river lit a fire on the way back to the village. This fire went out of control within the village. Often locals while walking to a particular location just light fires along the way with apparent reason or purpose.

Uncontrolled fires

Informants from the six villages collectively stated that even when fires are lit deliberately for a specific management purpose, they are known to get out of hand during dry seasons where there are high winds. According to an informant in Bopirumpun village, in 2016 a fire was lit to burn off Kunai grass for a small garden beside the village. The presence of strong winds and fuel (dry Kunai grass) the fire changed its direction and headed towards the village burning two houses and a small scale poultry farm. An informant in Sankiang village stated that controlled burning was done to formulate fire breaks in a garden. The change in wind direction caused the fire to burn three houses in the village. Informants generally stated that uncontrolled fires can also stem from deliberate lighting to cause destruction and those lit for amusement purposes.

Supplementary interviews (June 2020)

The supplementary interviews essentially supported the findings of the initial research. The findings were that fires are usually lit during the dry season and are used for a variety of reasons. Fires are used as a tool for hunting. Grassland areas are burnt to isolate prey such as wild pigs, bandicoots and grass land rats. Land clearing and burning of organic debris for new garden preparation is another use of fire. Some fires are lit without apparent reason and can be attributed to fires being lit for "fun".

Discussion Conclusions

There are a number of interesting conclusions from this exploratory research.
A preliminary point is that there were no reports of non-anthropogenic fires and informants, either from RAIL or community informants, who believed that all fires are lit deliberately, for a variety of reasons. According to Will Unsworth (pers comm), it is theoretically possible that events such as lightning could cause accidental fires, but highly unlikely. The combination of dry fuel and lightning makes naturally-caused fire possible, but the fact is that lightning in the RMV is usually accompanied by heavy rain, which suggests that fire caused naturally by lightning is unlikely.

The most important conclusion from the paper is that there are a variety of causes behind the lighting of fires. The stereotype which sees “just for fun” as a major factor is certainly exaggerated. Most fires are lit for a purpose, either positive or negative. And some get out of hand accidentally, essentially as a result of poor control, causing unintended damage.

It is also clear that there is a variety of reasons for fire lighting that are related to NRM, including clearing land for gardens, and lighting fires in grassland for hunting or controlling grass. On the basis of this research it is possible to suggest as typology of causes, as set out in Table 3.

Table 3: *A typology of fire causes and motivation*

Typology of Fire Lighting Events	*Nature*	*Specific Activity*	*Description*
NRM Management	**Deliberate**	Hunting	Mostly during dry season to hunt for Grassland Rats, Bandicoot and wild pigs
		Slash and Burn Agriculture	Either to burn piled slashed kunai grass or clear burning the kunai to make way for gardens
		Tree regeneration for Usage	Burning of tree stumps allows an adequate regrowth of trees for the purpose of obtaining wood for house construction
		Kunai Grass Regeneration Usage	The burning of the kunai grass allows a healthy regrowth for subsequent harvest and use for house roofing.
Conflict(Vengeance, Jealousy, Disagreement)	**Deliberate**	Lighting of fires in gardens, agroforestry plots/cash crop plots	Jealousy stemming from a successful cash crop yield (mainly cocoa); Vengeance from arguments/disagreements among villagers
		Lighting fires in RAIL operational sites	Disagreement, Conflict with RAIL causes fires to be deliberately lit in company operations (Mostly sugar, oil palm and forestry blocks)
Amusement	**Deliberate**	Random lighting of fires in areas near Villages	Random lighting of fires for amusement purposes. There is no apparent reason why these fires are lit
		Random Burning beside/in RAIL Operational Areas	

Again, we need to stress that this research is preliminary. It nevertheless suggests that the causes of fire and motivations for fire lighting in the RMV are varied. Developing strategies to reduce the incidence of damaging fire will depend on a nuanced understanding of the varied causes of fire.

We suggest that one aspect of improved fire management will involve greater cooperation with local communities. The experiences of an earlier ACIAR project in the RMV gives some examples of such cooperation. Holzknech (2014, p. 13) reports that local landowners developed an effective methodology “to avoid damage by grass fires”. Read (1950) in an early paper on social organization in the Upper Markham Valley, discusses some aspects of social practices related to fire control.

Tools developed by researchers concerned with evaluating the causes of peatland fires in Indonesia in collaboartion with communities (Applegate et al., 2017) could potentially be modified for applictaion to grassland fires in the RMV.

There are a number of possibilities for further research on anthropogenic fire in the RMV. One possibility is to implement a follow up study which aims to quantify the relative extent of the various types of causes of fire. However, such a study would be complex and, we would suggest, the selection of interviewees would be problematic. People who do light fires in order to deliberately cause damage are unlikely to be frank about their motives. We suggest the more useful direction of research would focus on understanding local practices of fire management and collaborative research with people involved in establishing forest or agroforestry plots.

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ANTHROPOGENIC FIRES IN THE RAMU-MARKHAM VALLEY: UNDERLYING CAUSES AND MOTIVATIONS

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ABSTRACT: Anthropogenic fires present a continuous challenge to landscape management in the Ramu Markham Valley (RMV) in Papua New Guinea. Aided by favorable climatic and weather conditions, topography and fuel availability these fires have proven to be detrimental to areas affected. The fires affect commercial plantation crops (oil palm and sugar), restored forests and locally established agricultural gardens. Strategies to reduce fire damage and incidence will depend on better understanding of the range of causes and, in the case of deliberately lit fires, understanding of motivations. Popular explanations of fire lighting behaviour tend to make simplistic assumptions about cultural practices, including the idea that "people just like lighting fires". Common cultural practice in the RMV see fires being lit for hunting, to prepare land for gardens and as a result of conflicts. It is essential to understand and differentiate between fires that are lit due to cultural practices and those that are lit to target the gardens of individuals or commercial crops. This paper reports on data on recorded fire events in and around Ramu Township and the area of operations of Ramu-Agricultural Industries Limited (RAIL). Evidence on the causes of these fires is presented and analysed in order to establish a typology of causes and motivations of anthropogenic fire in the RMV.

Agroforestry interventions at Ramu: The process and rationale for the approach

Robert Fisher, Melinda Thom, Nathan Wampe and Jack Baynes

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Final report September 2022

Aims of the report
The primary aim of this report is to present an account of project activities related to farmer-based agroforestry in project sites in the Ramu-Markham Valley (RMV) including a status report as at the end of June 2020. The underlying aim is to explain the rationale for the approach taken, which is essentially based on action research.

The report includes details on the interventions in Atzunas, Marawasa and Bopirumpun. Marawas is included, even though work there was discontinued, because this detail illustrates the process of project intervention.

This report is intended as a working paper, as the research and social processes described are necessarily continuing. The report includes a brief summary of key priniples for agroforestry extension (Attachment 1) and a Protocol for community case studies related to family focused reforestation (Attachment 2)

Introduction

The project activities related to farmer-based agroforestry at Ramu are:

- Project Objective 1 "*To design and test novel tree-based livelihood systems for family-focused community-based reforestation*".

  The report refers to Activity 1.4 and in part deals with the establishment of livelihood systems established, noting that this process is in an early stage due to the late commencement of the project. In fact the trials were only planted in 2020 and have therefore produced no livelihood results.

- Project Objective 2 "*To identify the methods by which family-focused community-based reforestation can be expanded to a greater number of clans*".

  In reference to Activity 2.2, this report provides an analysis of social including clan level dynamics and links these to the rationale for the intervention processes.

  Regarding 2.3, the report demonstrates that scaling up cannot be undertaken separately until the pilot tests have been established and demonstrate outcomes.

Essentially, these two objectives deal respectively with pilot testing farmer-based agroforestry systems and scaling up the implementation of these systems.

In practice the separation of pilot testing and wider implementation has been demonstrated to be unrealistic both for practical and methodological reasons and pilot testing and expanded implementation have been taking place in parallel. Firstly, the pilot testing did not begin until after the 2018/2019 wet season due to the delayed project starting date and the pilot testing on trial plots has therefore not been fully implemented and certainly has not been completed. Further delays from February 2020[1] arise from drastically reduced activities in PNG due to the COVID epidemic. Expanding implementation of field trials cannot be based on incomplete results.

The second reason why separation of pilot testing and wider implementation cannot easily be expanded is that the pilot process makes sense if it involves a wider variety of interested farmers. Identifying individuals to work with necessarily involves cooperation with clans, at least in seeking agreement about activities. Selecting very limited numbers of individuals following extensive discussions and negotiations with and within communities raises expectations. These negotiations may identify additional individuals with potential interest in trial plots. Restricting numbers frustrates expectations.

The overall approach requires careful investigation and negotiations. Selection of farmers can only be done by investigation of land access (tenure) including identifying existing or potential conflicts. This is a continuing process as issues emerge at different stages of the testing and implementation process. Phases of investigation, negotiation and implementation overlap and research into the social dynamics is necessarily ongoing. Research and implementation are not separate phases. Pilot testing and expanding the pilots take place concurrently in the same villages with the same clans. Expanding field trials takes place within the original clans involved in pilot testing at this stage. The overall approach is explicitly a form of action research in which intervention and research occur simultaneously. The research informs action and simultaneously observing intervention provides methodological findings about extension methods. (For an overview of the action research methodology applied see Fisher 2013.) Testing this approach to understanding the social aspects of intervention seems likely to be a significant methodological finding of the project.

The application of a slow and patient process of intervention is both inevitable and necessary. The experiences of Phase 1 of the project (FST/2011/057) demonstrated clearly that without detailed understanding of social dynamics planned activities can fail. Often things go wrong even after extensive investigation and negotiation. This demonstrates that monitoring though continuous visits and discussions is essential.

Features of social organisation relevant to negotiations and decision-making over land use

In Phase 1 of the project, the initial focus was on community forestry in the form of action by “communities”, clans, sub-clans or interested members of these groups to collectively manage forests. Experiences suggested that community forestry at the group level is difficult to achieve. Based on those experiences, the current project shifted to an approach which aimed to combine livelihoods and landscape restoration through farmer-based agroforestry. This, however, is not

[1] No field visits to PNG by Australian staff occurred after Febuary 2020.

simply a matter of working with individual farmers, but also requires negotiations with clans. There are two reasons for this:

- Clans in Ramu (as elsewhere in PNG) own almost all land and land use needs to be agreed by the clans.

- As clan membership and land access in the RMV are inherited patrilineally, individual clan members are male. The family plots are allocated by the clan. The individual rights to these plots can be inherited, but remain under clan control. Changing traditional types of land use tends to require agreement by the clan.

Clans have a variety of functions, such as ownership of land and regulation of land use and mutual defence (including against other clans).[2] They do not usually participate directly in economic activities as a group. Economic activity remains for individual clan members or small groups (usually involving close kin). Thus, the implementation of externally promoted agroforestry initiatives involves an interplay between the interests of the land-owning clan and individual members of the clan.

Regarding the point that clans do not usually engage in economic activity on a collective basis (especially in the RMV), the government has introduced Incorporated Land Groups (ILGs) which provide clans with legal personality that enables them to negotiate contracts, obtain loans and deal, as clans, with commercial operations such as logging and mining companies. Enabling relationships with businesses was the main intention of the relevant legislation.[3] In practice ILGs may involve multiple clans. Ideally all members of the clan are required to be members in order to benefit from ILG activities. However, forming an ILG is a complicated and expensive process and many clans have not formed ILGs at this time. In the absence of ILGs, an alternative and informal mechanism has developed. This is the Clan Land Use Agreement (CLUA). CLUAs do not have full legal status but enable businesses and clan members to commit to agreements and have some confidence in them.

A further feature of clans relates to the nature of leadership. Clans (certainly in the RMV[4]) do not have officially elected leaders or leaders appointed by government. Generally, leaders achieve their role due to individual skills, alliances with other individuals and wealth. The positions are not passed on automatically to descendants, although fathers may pass on some of the attributes of leadership (such as wealth or networks of allies) to sons, making it easier for the sons to become leaders. Leadership is achieved by influence and prestige. In anthropological terms leadership is achieved, not ascribed.

A further important point is that there may be multiple individuals who are influential (and therefore regarded as leaders) in a clan. These people may be allies, or may be rivals. All this complicates decision-making and may make it very difficult to identify agreement or underlying conflict.

[2] For a description of social dynamics, collective action and decision making in the RMV see Fisher, 2017. For further details see Wiset et al. 2022.
[3] The Land Groups Incorporation Act, 1974 (amended 2009).
[4] Clan leadership, like other aspects of social structure, are enormously diverse in PNG. Nevertheless, while details differ, clan ownership of land is virtually universal, although shifts towards greater development of privatised land are evident in some areas.

The links between clan membership and lands owned by the clans are complex. Clan lands may not be contiguous territories and different portions of clan lands may be separated. Importantly, clan members do not necessarily live on clan land. They may live in villages or hamlets with members from more than one clan. Clans (in the RMV) are not necessarily, or even often, territorial units. Nevertheless, the ownership of clan land, wherever located, belongs to the clan as a whole. In the RMV, clan membership is patrilineal.

One consequence of dispersed residence and the common distribution of clan lands in mosaic patterns, is that activities on land owned by one clan may affect other clans, so other clans may have an interest in land use decisions regarding land belonging to one clan. ILGs with members of multiple clans reflect the fact that commercial land use may involve land belonging to more than one clan and thus require negotiations between and cooperation between clans.

The approach to intervention

The points made above provide essential sociological/anthropological background to the following account of interventions at Ramu.

The approach taken at Ramu was based on the following steps:

- A "getting to know each other phase". This involved initial visits to potential sites to introduce the project to leaders. This was followed by meetings (possibly several) with community members to introduce the project.

- Combination of meetings with different groups and walk-around interviews to obtain wider views. This included an emphasis on discussions with women (separate from men as far as possible) and discussions with people who are not interested in becoming involved with project activities. It is important not to assume that all views are expressed at meetings. Non-attendance can be significant and may represent opposition as opposed to lack of interest.

- Consideration of the interests of landowners beyond the site (ie members of other clans and sub-clans). This helps to identify potential conflicts.

- Continual checking community interests and modifying the approach is necessary. These activities required multiple visits over an extended period of time.

History of intervention

The work at Ramu on farmers' agroforestry plots commenced in early 2018, having been delayed by the late effective start of the project. Several "communities"[5] were selected as potential case study sites. After initial contacts and investigations, some potential sites proved to be unsuitable. Atzunas and Marawasa were selected as pilot communities. Investigations took place into community structures and relationships, aiming to identify both potential issues and levels of interest. Following the initial investigation, negotiations took place with clan

[5] The term "community" refers loosely to a group of people who self-identify as coming from a particular area with some shared characteristics. The term is used locally, but is not an official administrative unit.

leaders and others in order to seek agreement for agroforestry trials. The intention was to support the establishment of a nursery at each site to provide seedlings. The nursery was to provide seedlings for farmers interested in establishing their trial plots. Training was to be held on seed germination and care of seedlings prior to planting. Tree seeds and basic equipment were also to be provided directly to selected/interested farmers.

As a result of discussion with the communities and consideration of available and suitable species, the plan was to plant pellita seeds in the first wet season (2018/2019) and to add cocoa in the following wet season (2019/2020). The pellita would provide shade for cocoa and other crops (vegetables etc) could be planted in the plots.

Atzunas

Introduction

Atzunas community is located within ward 4 of the Umi Atzera Local Level Government (LLG) of Markham District, Morobe Province. Ward 4 is shared by Atzunas and Tumua village. The initial visit by the project team on 19 April 2018 was to introduce the project and find out the interest of the community in planting trees.

Geography and Social Organisation

Atzunas community consists of 3 Hamlets: Omang, Ibuang (main village) and Mansbek. See map. There are 8 clans within the Community: Namisunang, Iyam, Aridagin, Poning Ragian, Sampai, Dampi Dampi, SasaunaiIraf and Yam yaup. Within these clans are several sub-clans. There is no specific clan living in a designated hamlet. Each clan has patches of land scattered around the community and as such people or families from the same clan settle at different hamlets to have the customary, social and environmental connection to their pieces of lands.

Population 2011 Census (Ward 4)

M	938
F	945
Total	1,883

Precise clan land boundaries are unclear, as people don't have designated boundary markers on their land, although they have traditional boundaries. The community members settled in smaller hamlets are usually settled close to their clan land. Although wards are official administrative units, ward boundaries are linked to community settlements and as such there are no clear boundary marks to separate each ward council. So far, no ILG has been established within Atzunas.

The basic units of the social structure are family units, either nuclear families or extended families. Non-kinship organisations within the community are church and sporting groups. Churches seem to be an entity that combines people to be organised and share responsibilities in any community as well as church work. Apart from these two types of organisation, the Atzunas community also has a Business Development Committee.

Land use

The major type of land use in Atzunas is semi-subsistence farming (mainly for domestic consumption with some sale of surpus production). Some farmers have integrated Cocoa cultivation within their gardens. The Atzunas community had a community cocoa project which did not eventuate further as there were conflicts about who was tasked with site maintenance. The problem has halted the activity, to date it is still unresolved.

Tenure

As is common in PNG, land is owned by the clan. Individual families have user rights over land. These rights are passed on within the family. Secondary rights are also present. An example would be someone who is married into a clan from Atzunas, who may be issued with secondary rights (user rights) only.

Land usage decisions are clan based. If decisions about land use are to be made related to the larger landscape (such as income generating projects), then the clan will decide. If a smaller landscape decision is to be made in relation to the surrounding garden areas or within the vicinity of family homes, then it is individually or family-based decision making. Where decisions refer to land owned by different clans, multi-clan negotiations are involved.

Land conflicts are solved in various ways depending on the magnitude of the conflict. If it is on a smaller scale, it is solved at a clan level between the clan leaders or sometimes in the presence of a village court magistrate. An example given was a conflict between two people from different clans having a conflict over a piece of land to make gardens. This problem was solved at the clan level as it is considered as an issue to be solved within the clan. If land conflicts are on a larger scale then the court systems are utilised.

Possible interest in agroforestry

During early field entry visits, quite a number of people expressed eagerness to plant trees.[6] The general expectation of the community initially was for the project to come in as a major development project, but it was clarified that the project is a research project in which the community themselves would take lead. It would involve small plots of land and the project would work with a small number of individual families. Another expectation was that the project would assist in developing a nursery at the community level and that each member would get seedlings from that nursery to plant.

The process of negotiation

Following the preliminary familiarisation phase, regular visits were made to Atzunas to negotiate regarding further plans and to investigate possible issues. This involved meetings with various groups, including clan leaders and the wider community as well as individual discussions.

[6] Kagl, Regina, Nathan Wampe, Melinda Thom and Bob Fisher (2018) “Preferences for family-based agroforestry in the Ramu-Markham Valleys.” Internal project report for ACIAR Project Enabling community forestry in Papua New Guinea (FST-2016-153).

Table 1 provides a summary of key events in the process at Atzunas.

Table 1. Dates and outcomes of meetings held between RAIL staff and villagers at Atzunas

Date	Meetings and key results
May 2018	A meeting was held with the Atzunas Community Chairman in which 16 men from the Namisunang clan expressed interest. The purpose of the project was explained and discussed.
June and July 2018	Further meetings were held with community leaders and members.
September 2018	The proposed CLUA and MOU was presented to the community chairman and clan leader (Simeon). They undertook to present it to the next clan meeting.
October 2018	The CLUA and MOU were signed.
November 2018	Nursery training was undertaken with 90 participants. 25 sets of nursery materials, *Canarium indicum* (galip) seed were distributed to people from Atzunas and outside communities.
January 2019	Four people have sown *Eucalyptus pellita* seed.
June 2019	Further training with 3 more participants was undertaken. The number of participants in Jue was now 8. One farmer had already planted seedlings.
June 2019	Field Trip to Umi Agroforestry Demonstration Plot. 7 participants from Marawasa and Aztunas attended
August - September 2019	Continuous participant assessment of seedlings raised in family-based nurseries. *E.pellita* was the common seedling raised.
January–March 2020	Series of out-planting activities by Atzunas participants. Assessment conducted to identify size of planting, species planted, location of planting, planting systems etc

An agreement was reached over time at the “community level” for the project to proceed and work with the Namisunang clan. It was left for the clan to decide which clan member would take on the responsibility of establishing a nursery. After the clan member was identified, an MoU defining the responsibilities of all parties was signed (10 October 2018). Further to this a CLUA was signed on the same date by the clan leaders, the ward councillor, a community spokesperson, a project representative and RAIL.

A community-wide (ie not clan specific) nursery training workshop was held (17 October 2018). Approximately 90 people attended with varying levels of participation. The nursery was then established and seeds and basic materials provided to the nursery operator. Others who expressed interest were provided with seeds, germination trays and sheets of green shade cloth. As some of these people came from more remote villages, detailed follow up has not been possible.

The nursery was completed in late December 2019 and seeds were sown in January 2020.

Four individuals from Atzunas, including the nursery operator were provided with pellita seeds. (Twenty other nursery training participants from other more remote hamlets were given Canarium *indicum* seeds.) The initial plan for the Atzunas four was to plant seedlings during the 2018/2019 wet season and to plant cocoa seedlings in the plots during the next wet season (2019/2020). However, this plan was dependent on the wet season continuing long enough for the seeds to germinate and seedlings to harden.

Of the four individuals from Atzunas originally given seeds:

- The seeds from the nursery were transplanted into poly bags to undergo the hardening process. However, they were not ready to be planted during the wet season.

- One participant was successful in preparing seedlings and planted some alongside a road extension (hoping for compensation if the trees are removed for road construction). Some seedlings were planted in his gardens.

- The other two Atzunas participants were unsuccessful in attempts to germinate seeds (due to incorrect soil preparation). They were subsequently retrained and given new seeds.

Subsequently further farmers expressed interest and were given pellita seeds and relevant materials for planting in the next wet season. As at the end of June 2019, the estimated number of seedlings to be planted in the 2019/2020 wet season was estimated at 620+. At the end of October 2019, considerable progress had been made and estimates for planting were much higher (see Table 2). These figures were conservative and were based on reasonable survival rates of seedlings in various stages of preparation. They include seedlings already planted or likely to be planted.

Table 2. Summary of progress with seedling preparation and probable 2019/2020 plantings at Atzunas

Person	**Estimated planting 2019/2020**
No 1 (Nursery manager)	180
No 2	120
No 3	200
No 4	100
No 5	100
No 6	200
No 7	415
No 8	Pending. Status not known
No 9	125
Total	**1,440**

During field visits to Atzunas in early 2020, it was observed that numbers of seedlings planted were often less than originally expected and that different combinations of trees and crops had been planted (for example using bananas to provide shade). These observations are important as they indicate:

(1) That farmers were willing to invest time in establishing plots (even preparing a plot and planting a small number of seedlings involves several days work). But it also show they were unwilling to invest larger amounts of time until the benefits were demonstrated.

(2) That farmers are active experimenters. They cannot be expected to establish agroforestry species mixes based on “packages” suggested by the project. They prefer to experiment and modify “packages”.

This suggests that the most important role for the project in providing technical advice is to train people on principles of spacing and similar practices, not trying to provide specific species mixes.

MARAWASA (Karanas hamlet)

Marawasa community is located in Ward 5 of Umi-Atzera LLG of Markham District, Morobe Province. The selected site within Marawasa is Karanas hamlet. Marawasa was earmarked as a focus community for the project and as a location for the establishment of family-based agroforestry trial plots.

Initially, the project opted to focus on Impu (within Marawasa). However, during the course of the investigation phase, it was found that Impu is actually a specific area of land that is owned by the Yaru clan and of which certain portions are managed by the Yaru Incorporated Land Group (ILG). As a result, in order to develop a more comprehensive overview of the community, it was appropriate to generally refer to Marawasa Community as a whole rather than Impu.

Geography and Social Organisation
The government recognised leader for Ward 5 is the elected Ward Councillor. Note that this position is an official position and does not equate to clan leadership, which is separate. There are four major clans in Marawasa: Yaru, Muansibingan, Birap, Angamp (Muansisi). No specific hamlets in Marawasa are occupied by a single clan. Mixed clans live within each hamlet.

There are six hamlets in the area which the residents identify as Marawasa “community”. They identify themselves as being from Marawasa. These hamlets are Karanas, Iris, Papua, Utungut Wasa, Reverse and Red Kona. Karanas is the major hamlet.

Population figures are not available for separate hamlets, but only by ward. The population of Ward 5 (effectively the Marawasa community) in 2011 is identified in Table 3.

Table 3: Population of Marawasa

Geographical Area	Household	Persons	Males	Females
Marawasa	321	1434	734	700

Source: (2011) National Population Census figures

There are non-clan members living in clan territories. These individuals settle through marriage ties and user rights agreements. Near the hamlets of Papua, Reverse and Red Kona there is a settlement which accommodates people from other parts of Papua New Guinea.

The only registered Incorporated Land Group (ILG) is Yaru ILG. This ILG was primarily established in order to manage the Oil Palm Development agreement between Ramu Agri Industries Ltd (RAIL) and the Yaru clan. The Yaru ILG is chaired by an appointed individual. Other ILGs are proposed for establishment due to the Ramu Hydro Dam development project. The proposed ILGs include: Muansibingan, Wagamaraburump, Angamp and Siriruwa.

Land use and land use interventions
Land in Marawasa is primarily used for semi-subsistence farming (mainly for domestic consumption with some sale of surpus production) . Shifting Cultivation is commonly practiced. Small scale cocoa cultivation incorporating agroforestry concepts is common in the hamlets of Papua, Reverse and Red Kona. In addition to semi-subsistence farming, there are also a significant number of commercial farming operations (ie involving commercial interests) in Marawasa.

- Impu is an area of land owned by the Yaru clan. Approximately 972 hectares of land are used for Oil Palm cultivation by Ramu Agri Industries Ltd (RAIL). This land is leased by Yaru clan to RAIL strictly for agricultural development (Oil Palm development) under a registered customary land lease in 0ctober 2016.

- Village Oil Palm (VOP) is a small-holder concept where selected villagers are given approximately 2 hectares to cultivate and harvest oil palm. Harvested fruits are then sold to RAIL

- Near Karanas Hamlet, PNG Biomass, a PNG renewable energy development firm, has used a total of 12 hectares to plant *Eucalyptus pellita* in trial plots. A Clan Land User Agreement (CLUA) form was signed by the Angamp (Muansisi) clan members with PNG Biomass. The firm facilitated annual payments for the land use.

- Plans are also underway[7] for a proposed Ramu Hydro project which will be facilitated by the Government through the state owned Kumul Consolidation Holdings Limited. Marawasa was identified as one of the communities that will be affected by this development project.

- Approximately 100 Ha of Impu land has been given to a Papua New Guinean owned trucking firm, Mapai Transport Limited to construct a container yard that will service Madang and the Highlands region. Yaru ILG has facilitated this development to take place.

The number of activities by various companies and organisations means that people are very busy and sometimes makes it difficult to meet people or organise meetings related to the project.

Tenure
Land ownership is clan based. Each clan is aware of their land boundary through natural feature markings such as tree lines, rocks, presence of vegetation or a body of water. Certain land utilized for activities such as gardening and house construction is family oriented. Rights to this land are inherited patrilineally (father to son), but ownership remains with the clan. Secondary rights also exist. An example would be someone who is married into a clan from Impu who will be issued with secondary rights (user rights) only.

Land-use decisions are based on the magnitude of intended land use. If decisions are to be made on a larger scale the clan will have to deliberate on this. If a smaller landscape decision is to be made in terms of the surrounding garden areas or within the vicinity of family homes, then it is an issue for individual or family-based decision making. This does not necessarily mean that non-clan members who are using the land will have a say in decision making.

> Case of outsider planting trees. (Karanas)
> Regarding the planting of trees on clan land, the general position is that planting trees on clan land is ok if there are only a few trees, but clan permission is needed for larger numbers of trees. The position if outsiders plant trees was discussed in a group discussion. It was agreed that a woman from the clan who married out but had returned to the hamlet with her outsider husband

[7] As at 2020

> would need her brother's permission to plant trees. There is a specific case of a man from Sepik, married to a woman from the clan who is now living in the village, who planted a large number of pellita, which he sells for K 50 each. He did not get permission, although he knew the rules. He is still harvesting. There appears to be some conflict about this, but it is not clear how it will be resolved.

Further information on this case is contained in an internal project report:

> Interestingly women who married out who have returned with their husbands from other provinces are respected, they are given the rights to speak and act on behalf of the women married into the clan. These women may be educated but will not have the rights to participate in any meeting because their husband will keep close watch and listen to what they have to say, and later they will question them and may be beaten up. One interviewee stated that: "I am from here, married to the man outside the province but I represent the women from Impu and also a member of Village Oil Palm (VOP), I noticed that, we are given more respect than the women married into our clans." The daughters that are married outside are given more rights and can make decisions alongside their fathers and brothers. The respect that is given to the women with husbands living with them is more. (Extracted from a report by Regina Kagl 2019)

The issue of the extent to which people (whether insiders or "immigrants") can plant trees for income generation has implications for the proposed family-based trials and should be continually assessed.

Land issues are solved depending on the magnitude of the conflict. Smaller scale land issues are solved at a clan level with the presence of either a village court magistrate, or between clan leaders.

Land conflicts that eventuate on a larger scale are solved or mediated through conventional legal proceedings. An example was the confirmation of the Impu land that RAIL is operating on. Yaru was recognized as having customary rights of the land through a court decision. This decision was reached when two other clans, Birap and Muansibingan declared Yaru's legitimacy. There are ongoing court proceedings which are related to land agreements.

Possible interest in agroforestry

A preliminary report was prepared on *Preferences for family-based agroforestry in the Ramu-Markham Valleys* (Kagl et al, 2019). According to that report the most recurring identified need from trees was for housing construction materials. This was based on a series of informants' suggestions that forests which had suitable trees for this purpose are non-existent within the community's vicinity. Following closely behind is the need for trees that will provide firewood. Other needs from trees included medicinal, food, cash income generated from timber and food sourced from trees. Shade trees were also a need due to their persistent small-scale cocoa cultivation using agroforestry concepts.

Consistent with successive interviews, female informants highlighted firewood collection and obtaining materials for housing construction as very crucial in sustaining their family's livelihood.

Other issues

Since PNG Biomass had previously established trial plots in Karanas there was subsequent confusion with the context of this ACIAR research project. The local informants envisioned that the project would provide timber or fuel wood trees and payment for the utilisation of the land**.** The forestry plots developed from the project were also expected to be on a larger scale. The research team made clear and concise explanations of the research project before progressing with the interviews. A clear understanding was reached between the team and the informants.

Brief history of project activities in Marawasa

The first scoping visits to Marawasa took place in April 2018.

Preparation for the trials involved extensive investigation of land tenure and potential conflicts as well as exploration of interest in agroforestry. Following the initial scoping there were frequent visits to assess interest, investigate land use and related issues and to carry out negotiations with possible participants and trials.

As with the other selected case study community (Atzunas) the project proposed to support a family-based nursery, to hold a nursery training workshop and to provide seeds and basic equipment to the nursery manager and other interested individuals to enable seeds to germinate and the resulting seedlings to be planted in individually owned plots. The plan was for pellita seeds to be provided for the first planting cycle with other trees and crops (especially cocoa) to be planted in the following wet season, when the pellita has grown sufficiently to provide shade.

Following investigations and discussions with a wide variety of stakeholders Karanas hamlet was selected for the nursery and trials. The Yaru clan became the principal actors. The Yaru clan leaders decided that two brothers would take the lead and establish and run the nursery. Table 4 presents the population of Karanas hamlet by clan.

Table 4: Population of Karanas by clan

Karanas Population. According to the Yaru ILG Chairman, the estimated number of houses in Karanas is 56. Assuming an average of six family members per household, the total estimated population is 336. In terms of the population of each clan, he did not know the exact number but came up with percentages for specific clans (out of 100%).	
Clan	*% present at Karanas*
Yaru	30%
Muansibingan	30%
Birap	20%
Angamp	20%

Before the activities could commence, a CLUA needed to be signed by the ILG executives and the project. An MoU was also required to outline the responsibilities of the implementing group and the project. These documents were signed in December 2018.

The nursery training workshop was held on January 2019. Equipment was provided for the nursery establishment. Seeds, germination trays and shade cloth were also provided to two interested workshop participants.

Although all the necessary materials were provided immediately after the nursery training and a trial plot had been demarcated, nursery establishment was not carried out. The issue was not a lack of clan or community support but a conflict between the two brothers. The younger brother claimed the older brother intended to be the sole beneficiary of the nursery. Efforts to resolve the conflict were complicated by difficulties in the availability of the younger brother for meetings. He was very active in other land-related activities occurring within the community. As explained above, there were a number of significant land-related projects with which Karanas was involved and this was a potential issue in terms of competition for time. The new project activity was to be a small activity operating in the context of several large projects.

By the end of June 2019, the conflict between the two brothers had not been resolved. The project team was reluctant to impose a solution, although the clan could presumably have chosen other nursery managers. The activities at Marawasa were discontinued, although some efforts to negotiate a compromise initially continued.

At present there is no apparent opposition to the project activity within the clan or elsewhere. However, the number of other externally sponsored activities affecting Karanas may mean that the nursery is not a high priority.

Bopirumpun

As an alternative to Marawasa, another potential community was selected in late June-early July 2019 for future activities. RAIL is well known at Bopirumpun and good relationships existed. This allowed a somewhat abbreviated process of fact-finding and relationship building. Preliminary visits suggested strong local interest and the community has since become heavily engaged with project activities, supported by nursery training activities. Activities at Bopirumpun are summarised in Table 5.

Table 5 Dates and outcomes of meetings held between RAIL staff and villagers at Bopirumpun

Date	Meetings and key results
June 2019	Initial introductory meeting with community leaders. Leaders expressed interest in the project and welcomed the activities in the Community.
July 2019	Initial Community Nursery Training held in Gaki Hamlet. Thirty participants from the community attended. Several participants expressed interest in partaking in the project
October 2019	3 Nursery training workshops were carried out in 3 hamlets in a space of three days. Approximately 50 people attended these trainings altogether. Several individuals expressed interest in partaking in the project.
November 2019	First Field Trip to Umi Agroforestry Demonstration Plot. 4 participants attended
November 2019	Nursery training was undertaken with 90 participants. 25 sets of nursery materials, *Canarium indicum* (galip) seed were distributed to people from Atzunas and outside communities.
January- February 2020	Continuous participant assessment of seedlings raised in family-based nurseries and assistance of basic materials in Bopirumpun . E.pellita was the common seedling raised, other species include, Kwila, Teak, *Eucalyptus terataconis.*
March- June 2020	Series of out-planting Activities in Bopirumpun by participants. Assessment conducted to identify size of planting, species planted, location of planting, planting systems etc

Table 6 presents the estimated number of seedlings expected to be planted at Bopirumopun in the 2019/2020 wet season based on seedlings then under preparation. These numbers were conservative because (a) they were based on reasonable survival rates and (b) they did not take account of a significant additional number of people who had expressed interest and attended recent training activities. Table 7 gives updated information as at June 2020.

Table 6. Summary of progress with seedling preparation and anticipated 2019/2020 plantings at Bopirumpun.

Person	**Estimated planting 2019/2020**
No 1	415
No 2	220
No 3	80
No 4	Joint with No 1
Total	**715**

Table 7. Updated list of information of plots /boundary plantings as of June 2020

Person No	**Gender**	**Seedlings Out-planted**
1	M	50
2	M	55
3	M	20
4	M	20
5	M	100
6	F	400
7	M	33
8	M	55
9	M	20
10	M	20
11	M	20
12	M	300
13	F	256
14	M	166
15	M	110
16	M	116
		1741

The accelerated process at Bopirumpun

We have described the accelerated process of intervention at Bopirumpun compared to the other two sites. We pointed out that the fact that RAIL had well established relationships at Bopirumpun enabled what seems like a short cut. Another important factor is that one member of the community had been actively engaged in agroforestry experiments on his own initiative for some years and he became effectively a lead farmer and was important in encouraging other members of the community to take up agroforestry activities. In fact farmers often acted on their own initiative once the process was initiated.

Overall comments on outplantings

Table 8 provides a summary of seedlings numbers planted from December 2019 to June 2020.

Table 8 Overall summary of seedlings out-planted during the wet season December 2019 to June 2020

Community	Number of Participants	Number of Seedlings Out-Planted
Atzunas	8	503
Bopirumpun	16	1741

While these numbers are quite small, it can be argued that an increasing number of interested farmers with relatively small numbers of seedlings offers more promise than a smaller number of farmers with more seedlings. We believe this is important *because it demonstrates a level of serious commitment combined with an understandable degree of caution*. Farmers are understandably wary of the outcome of what they see as experiments. They naturally favour experiments that do not involve large investments of time with uncertain outcomes.

Discussion

In preparation for field activities at Ramu, a Protocol for Community Case Studies was developed in consultation with field staff. This document is attached (Attachment 2).

In both Atzunas and Marawasa, the project engagement and research protocol was followed closely. In both cases an appropriate clan was identified and the appropriate agreement was reached after considerable investigation and negotiation. In both cases the cautious process avoided potential conflicts within the clans and with other clans. The problem that arose at Marawasa emerged very late and was between two brothers, not between clans or within the selected clan as a whole. The Marawasa case does show how barriers can arise unpredictably despite cautious intervention.

What these experiences demonstrate is that a strictly linear model for intervention is unrealistic. Such a model would involve several steps:

- Investigation
- Negotiation
- Implementation
- Monitoring and follow-up.

The alternative is to introduce the steps in the order outlined, but to run the new steps while continuing the earlier ones. Specifically, investigations, negotiation and implementation need to continue to be run in parallel. This is the process followed at Ramu.

Experience from Phase 1 shows that conflicts need not be visible or even active. Some potential conflicts emerge as a response to new developments. For example, rival claims to benefits from portions of clan land may only become active if that land becomes profitable due to new project activities. Consequently, any new activity may have unpredictable consequences.

Although the project approach at Ramu has resulted in slow implementation, this patience has been essential. Several of the pilot areas originally considered failed to work out. Patience allows these "false starts" to be identified before undue time and effort has been invested. There is, however, a reciprocal risk. A slow process may raise expectations and lead to some levels of frustration about lack of progress.

We believe the social process followed is essential. Without carefully working with the various actors, failure will be very common.

The models under development for the farmer-based agroforestry trials are of two kinds. The first is a model for the approach to intervention. The second is a model for agroforestry "packages". This report deals mostly with the first topic. For the second, the process is only beginning and the effective timeframe of the project due to COVID cut the process short. In any case, we believe that the development of extension packages is necessarily a slow process as options need to be tested in the field and must include cautious testing of suitability by farmers. It is clear that, even without long delays caused by the COVID epidemic, a five year project does not not provide enough time either for establishing nurseries and trials (as all foresters know, growing trees takes time) or for the social processes of negotiation and evaluation by farmers (social processes also take time).

It is clear that the "packages" or systems developed will need to be flexible, as the interested farmers have differing needs and preferences and will modify packages and experiment.

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Attachment 1

Note: *This attachment should be read as an introduction to Attachment 2.*

Some Key Principles for Agroforestry Extension Interventions

Agroforestry extension is necessarily a co-learning approach involving extension staff and communities.

It is best understood as a form of action research involving continued cycles of planning, acting and observing and reflection.

Identifying stakeholders and understanding their interests is essential. Identify the categories of stakeholders who might have different interests and expectations about project interventions. These include local leaders, male and female farmers and others. Don't assume that all men or all women have the same views and expectations, so look for varied opinions. Include people who are not interested in activities to find out why. This may help to identify specific problems or conflicts. As work continues new groups of stakeholders may be identified.

There are two broad types of stakeholders:

- people who are affected (negatively or positively by an activity
- people who can affect (positively or negatively) the outcomea of an activity

Be aware that conflicts may develop as a result of interventions and may not be predictable.

Consider members of other clans, especially landowners whose land is near the area where project activities are proposed.

Avoid one-off surveys as circumstances and opinions may change. Continual monitoring is important.

Find out what people want and need rather than starting out with predetermined outcomes or packages.

Casual discussions ("walk and talk") are often the best way to establish rapport and obtain information.

Attachment 2

Protocol for community case studies related to family focused reforestation (Objective 1)

ACIAR PROJECT FST-2016-153
Enabling Community Forestry in Papua New Guinea

Prepared by
Bob Fisher
Senior Research Fellow
University of the Sunshine Coast

21 March 2018

NOTE: This is a preliminary draft for discussion before fieldwork commences.

Introduction

The underlying purpose of the activities involved in this aspect of research under project Objective 1 is to support field trials of family-based reforestation[8] in case study landscapes. This will be supported by technical advice on species which meet local needs. In order to establish these trials detailed understanding of existing landuse patterns in the landscape, land access by families and land-use decision-making by landowners is essential. Areas of existing or potential conflict will also need to be understood. The preliminary investigation phase of the study will be about building a community profile. The second phase will involve identifying case study families and negotiating with other stakeholders (especially clan members) about use of clan land by families for the trials.

A major challenge during the investigation phase will be to avoid raising expectations about benefits from the project. This will be tricky because we need to mention the possible family-based trials and we also need to identify some interested people without creating wider expectations.

NOTE: This document focuses on the investigation phase. The approach for the negotiations phase will be further developed during the investigation phase.

[8] We understand "family-based" to mean family (household) or small group based. These small groups will usually consist of close kin.

Summary of phases:

Investigation phase. The first round of visits will take place 20-31 March.
Outcome: A good overall picture of the case study landscape, including major stakeholders. We also hope to have a very preliminary list of potential families to work with on family-based trials.

Follow-up: Continued visits by RAIL staff. Between the first round of visits and the first major negotiation/planning phase (May 2018), RAIL staff will continue low key visits and preliminary planning discussions (depending on the outcome of the first round) in preparation for the negotiation/planning phase. A separate exercise will be carried out in April to identify desired landscape services and preferred species.

Negotiation and planning Phase: (May 2018)
This will involve a mix of informal and formal negotiations (at hamlet and landscape level) about family-based trials (to confirm clan agreement to family activities on clan land). Research will focus on documenting the decision-making process. Time will be allowed for

Ethics/RPIS

The human research ethics process requires us to inform participants about the project before involving them in the project. We should carry copies of the tok pisin version of the RPIS with on field visits. When introducing the research we should cover the main points in the RPIS, especially:

- Research aims. We are aiming to look at possibilities for agroforestry to be used to restore the landscape and contribute to livelihoods. Later we hope to support a small number of family-based trails. First we need to understand how people use the landscape.
- Benefits. If the trials are effective, community members may decide to implement similar approaches.
- Voluntary nature of the research and right to withdraw at any time;
- Confidentiality of data which will not be linked to their names unless they ask to be identified.

If anybody wants a copy of the RPIS, it should be provided.

When we are doing the walk-around informal survey, the ethics information should be given the first time we meet people. It is not necessary to repeat it when we meet the same people. Whenever there are meetings (at various levels), the process should occur. In a repeat meeting where there are no new participants, there is no need to repeat, although a reminder might be appropriate.

Methodology

Entry protocol. On entry to each community the team will first meet with village leaders to explain the activity and project aims. This process will follow RAIL's normal and well tested practices. In fact, RAIL researchers will have already made some arrangements and introductions before field visits occur.

The investigation phase will be based on qualitative methods, especially informal ("walk around") surveys and small group discussions. The aim will be to visit all hamlets in the selected landscape and meet with individuals or small groups in the village or fields. Questions asked will be based on topics identified below. While the questions will be planned before discussions, the process will be more in the form of a dialogue than a semi-structured interview.

Participants must include a range of stakeholders, including village leaders, people with a demonstrated interest in trees, residents who are not members of the landowning clan. A significant number of women will be interviewed, as far as possible without men present.

During discussions, further participants who are likely to have relevant perspectives will be identified and interviewed (snowballing sampling).

Topics/information required (investigation phase)

For each case study landscape an overall profile will be developed. Existing information available from RAIL will be used where available.

Identification of landscape: This will generally be at clan territory level, but others may be stakeholders and need to be identified.
What are the clan boundaries? (Prepare sketch map or use RAIL map where available.)
Identify the stakeholders, especially land users. Are there any outsiders (non-residents) with secondary rights to the land.
The first round of stakeholders will be identified based on existing knowledge. Further stakeholders will be progressively identified through "snowball sampling".

Decision-making:
How are land use decisions/allocations decided? – by whom? what issues etc?
How is land passed on or alienated, if at all?
Are resident non-clan members allocated land? On what basis?
Note: We know a lot about these issues <u>in principle</u>, but we need to identify different (potentially conflicting) viewpoints.

Women: Where do they work? What do they do? What limitations exists?
Role in decision-making? Formal/informal? About what?

Indications that people are interested in family-based agroforestry:
Are any informants experimenting with new crops or other innovations? Tree-planting?

See also Appendix.

Reporting

A separate report should be prepared for each site for each visit or round of visits.

Each report should include detailed information from each interview/discussion. Participants should not be identified in the circulated reports. A list of people interviewed should be kept in field note books with names listed against a identifying number. Only the numbers should be given in reports.

There is no specified structure for reports but they should all contain the following elements:

- Introduction
  - Authors
  - Location
- Date of visit
- Purpose of visit
- What was done? Who met?
- Data/findings
- Analysis/conclusion (including recommendations for follow up) – author's opinions etc.

[Unnecessary text deleted here]

Appendix

(1) Obtain a broad overview of community structure: clans, leadership, institutions. This will include identification of clan land boundaries, participatory mapping of agricultural plots, identification of possible competing land claims.

(2) Obtain an overview of agricultural practices, livelihoods, outside employment etc. (Detailed quantitative data not necessarily required.)

(3) How have decisions about forest use and management been made by the community?
  - What information is taken into account?
  - Who (which individuals or groups of individuals within the community) makes the decisions?

(4) What are the information gaps (such as knowledge of markets and market change) that could contribute to more informed decision-making?

(5) Given that landownership is clan based, how are decisions made about individual and family access made? What factors affect decisions? What types of activities are acceptable? Are innovative activities acceptable?

(6) What is the history of local level forest management within the community involved?

(7) What interventions by outside agencies including government and NGOs have occurred?

(8) What are the objectives of various stakeholders in the community for forest use and management?

(9) What constraints or enabling factors assist or hinder the achievement of these objectives? (This includes economic, financial and policy constraints.)

SYNERGIES BETWEEN FOREST LANDSCAPE RESTORATION AND AGRICULTURE IN THE GRASSLANDS OF PAPUA NEW GUINEA

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ABSTRACT: If forest restoration is to succeed at a landscape scale, the example of Ramu Agri Industries Ltd (RAIL) illustrates how industry and restoration objectives may be combined. In Papua New Guinea (PNG) the anthropogenic grasslands of the Ramu/Markham valley (RMV) have long been under-utilised. Uncontrolled fires have caused a continual retreat of native forest from the valley floor to steep hillsides. However, membership of the Roundtable on Sustainable Palm Oil (RSPO) has provided RAIL with the impetus to reforest a substantial amount of environmentally sensitive land adjacent to watercourses. In possibly the most species-diverse nursery in PNG, RAIL grows many seedlings. Fire protection for oil palm plantations has also protected newly planted forest, although losses have occasionally been severe. Land tenure is secured through long term leases of grass which cannot be otherwise used by traditional owners. RSPO certification also provides for monitoring, reporting and verification of reforestation activities. Although the area of land reforested is not large compared to the land which is allocated to agriculture RAIL's commitment to restoration is the biggest commitment to durable restoration in the RMV, so far.

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What could forest landscape restoration look like in the Ramu-Markham Valley of Papua New Guinea?

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Papua New Guinea

ABSTRACT

Implementing global environmental initiatives at the local level requires modifications to accommodate site-specific factors such as social organisation, land tenure and gender. This is particularly challenging for forest restoration initiatives such as Forest Landscape Restoration (FLR), which require the cooperation and support of local communities and families. FLR has been developed as a global approach to forest restoration supported by various sets of guidelines and principles which may not fit local contexts. In this paper we explore how the local context of the traditional social organisation and gender roles in the Ramu-Markham Valley (RMV) of Papua New Guinea (PNG) could fit with a broad approach to FLR. We investigated villagers' perceptions, preferences, gender roles and decision-making related to landscape restoration at the family and clan levels in three villages in the grasslands of the RMV. First, we confirmed that small-scale initiatives implemented with families better matched the traditional land use customs compared to a whole of landscape scale approach. Second, a family-based approach fitted with informants' preferences on land use practices and accommodated shared decision-making of men and women within the family or household. Third, we found that the preferences of women and men often differ in terms of the types of services they want from trees and the preferred locations for planting. Fourth, we found that landscape restoration through agroforestry generates multiple benefits for livelihoods and the environment and can be incorporated into existing farming practices. Fifth, while FLR literature advocates a negotiated approach to managing landscapes as a mosaic of different uses rather than a planned approach, we found that neither a negotiated or centrally planned approach at a landscape level is practical in the RMV, because there are no decision-making social or administrative institutions that operate on a "whole of landscape scale". Landscape restoration is in a preliminary stage in the RMV. This research suggests that the results of expanded efforts would meet the higher-level objectives of FLR: enhancing human well-being and regaining ecological functionality by applying an adaptive approach. We suggest that large numbers of small-scale farmer-based initiatives, at a family or clan level, have the potential to contribute to the higher objectives of FLR across a forest landscape.

1. Introduction

Implementing global environmental development initiatives at a local level can be challenging due to neglect of the social factors which motivate the actions of local people (Venugopal, 2018). Crucial obstacles identified are forms of land tenure and rights over resources and benefits (Corbera et al., 2011; Sunderland et al., 2014; Paudel et al., 2015), lack of accommodation to local livelihoods (Blom et al., 2010; Leggett and Lovell, 2012; Sunderlin et al., 2014), and ignorance of cultural contexts (Blom et al., 2010; Leggett and Lovell, 2012; Howell, 2015).

Forest Landscape Restoration (FLR) is a key approach to addressing

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Table 1
The three sets of principles of FLR.

FLR principles of Maginnis and Jackson (2007)	Landscape approach principles of Sayer et al. (2013)	FLR principles of Besseau et al. (2018)
1) FLR is a process 2) FLR seeks to restore ecological integrity 3) FLR seeks to enhance human well-being 4) Implementation of FLR is at a landscape level	1) Continual learning and adaptive management 2) Common concern as entry point 3) Multiple scales 4) Multifunctionality 5) Multiple stakeholders 6) Negotiated and transparent change logic 7) Clarification of rights and responsibilities 8) Participatory and user-friendly monitoring 9) Resilience 10) Strengthened stakeholder capacity	1) Focus on landscape 2) Engage stakeholders and support participatory governance 3) Restore multiple functions for multiple benefits 4) Maintain and enhance natural ecosystems within landscapes 5) Tailor to the local context using a variety of approaches 6) Manage adaptively for long-term resilience

the Bonn Challenge of bringing 350 million hectares of degraded and deforested landscapes into restoration by 2030.[2] The Bonn Challenge, launched in 2011, was supported by The New York Declaration on Forests at the 2014 UN Climate Summit as a means of action to halt global deforestation.

A set of principles for FLR was developed by Maginnis and Jackson (2005, p. 19).[3] They are embodied in the following definition:

1. *"FLR is a process."* Process implies *"(i) it is participatory; (ii) it is based on adaptive management and thus responsive to social, economic and environmental change; and (iii) it requires a clear and consistent evaluation and learning framework."*
2. *"FLR seeks to restore ecological integrity."* It needs to meet a mix of functions to meet the requirements of various stakeholders.
3. *"FLR seeks to enhance human well-being… the joint objectives of enhanced ecological integrity and human well-being cannot be traded off against each other."*
4. *"Implementation of FLR is at a landscape level: this does not mean that FLR can only be applied on a large scale, but… that site-level decisions need to be made within a landscape context."*

Subsequently revised sets of principles have been presented as guides for implementing FLR (Sayer et al., 2013; Besseau et al., 2018). These principles focus on the landscape level, participatory governance and gender, multiple functions for multiple benefits, enhancing natural ecosystems, tailoring to local contexts, and adaptive management and resilience (Table 1). Although they use different terminology, the three sets are similar in terms of some higher order principles: they each stress an adaptive process, the dual aims of achieving benefits for people living in the landscapes and contributing to ecosystem functionality.

In the literature, FLR is widely understood to relate to outcomes that are negotiated by stakeholders rather than planned by experts or leaders (Fisher et al., 2008; Sayer et al., 2013), and to apply to landscapes which consist of a mosaic of different types of land use (Fisher et al., 2008). Chazdon et al. (2017) noted that a broad understanding of socio-economic and environmental contexts is needed for implementing FLR. Stanturf et al. (2019) observed that the complexity of socio-ecological systems in each landscape provide different challenges and opportunities for FLR implementation. There is no one-size-fits-all for FLR implementation.

The importance of matching FLR to context is clearly acknowledged in the literature. This paper accepts that point, but aims to demonstrate that understanding local context requires intensive investigation as a first step in implementation.

The focus of this paper is a case study from the Ramu-Markham Valley (RMV) in Papua New Guinea (PNG). The aim is to use this particular socio-cultural context to reflect on the relevance of FLR principles and to consider what FLR could look like in the RMV if the current activities are expanded. The paper explores the issues involved in a local case study in PNG, where almost all land is held under customary land tenure, providing an unusual context for exploring landscape restoration under distinct local conditions.

The research has been undertaken as part of a project concerned with reforestation in the context of the development of "community forestry" in the area.[4] A separate earlier research project had experimented with an area-based (multi-clan) nursery to support reforestation.[5] According to Holzknecht (2014) this was not an effective level for nursery management and the nursery was eventually managed by a paid employee. The first phase of the current project focused on clans and sub-clans as the relevant institutions. Experiences within the first phase led to a shift away from clan or sub-clan activities towards experimenting with reforestation through agroforestry with individual families or very small groups of close kin. Clans remained important as the landowning institution. This current phase was the first of the three projects to be specifically linked to landscape restoration or FLR as an approach.

Previous research in the RMV has addressed some of the factors which influence farmers' actions in tree growing and agroforestry (see Mulung, 2012; Kanowski et al., 2014; Baynes et al., 2017). However, there is little information concerning the interests and perceptions of local people in relation to tree growing, particularly the local preferences for particular practices and the influence of gender roles on preferences for tree growing (e.g., species, location and planting patterns) and decision-making at family and clan levels. This paper provides further detail on women's preferences on tree planting and cropping patterns.

It is important to recognise that PNG society is incredibly diverse. This paper focuses on the RMV and the findings cannot simply be generalised to PNG as a whole. Nevertheless, some of the insights gained about the RMV may be relevant to other parts of PNG and hopefully elsewhere in the world.

2. Background to PNG and the RMV

In PNG, 97 % of the total land area is held under customary ownership (Anderson, 2010; Blaser, 2011) which is recognised by the constitution. This land is generally owned by clans, and managed according to traditional customs (Anderson, 2010; Yosi et al., 2011; Bun, 2012). Clan-owned land is often held without surveyed boundaries (Filer, 2007) or formal land title (Koczberski et al., 2017). The clans retain land ownership and allocate rights to use portions of land to their members (Mullins and Flaherty, 1995).

The nature of clans and the associated right to inherit land varies. In much of mainland PNG, inheritance of land rights and clan membership are patrilineal, meaning that they are passed along the male line.

[2] https://www.bonnchallenge.org, accessed on 9 April 2020
[3] Republished as Maginnis and Jackson (2007) (pp. 10–11).

[4] The current project, "Enabling Community Forestry in Papua New Guinea", is funded by the Australian Centre for International Agricultural Research and implemented by the University of the Sunshine Coast. The first phase commenced in 2013 and is now in the second phase, scheduled to end in late 2021. The project works with local partners. In the Ramu-Markham Valley the partner is Ramu Agri Industries Pty Ltd. Two of the co-authors were employees of the partner at the time the research was conducted.
[5] ACIAR project FST/2004/050 ("Value-adding to PNG agroforestry systems").

Matrilineal inheritance, in which membership is passed on through the female line, is less common. In the patrilineal system, all male members of the clan are joint owners of the clan land. Men (and in some cases, women) are allocated the right to use land for vegetable gardens but use generally must be acceptable to clan leadership. Where land inheritance is patrilineal, men tend to control land use decisions with women taking a subordinate role (Sillitoe, 1999; Koian, 2010).

In the RMV area, the system is patrilineal. The traditional role of clans in land tenure and land use was described in early ethnographies of the RMV (Read, 1950, 1954; Holzknecht, 1974). Clan members share common rights and obligations (Read, 1954). Land is allocated to individual male clan members for farming and gardening (Read, 1950). Individuals can seek land for specific use by seeking approval from clan leaders and elders (Kanowski et al., 2014). Importantly, land use for commercial purposes, such as planting of trees for sale, may depend on clan decisions (Mulung, 2012). It is important to stress that land is owned by clans, but individuals have rights to individual plots. This pattern continues as confirmed during this research.

Clans own the land, but clan members do not necessarily live within clan land. In fact, clan members may live in villages on land owned by other clans and members of multiple clans may reside in a single village. Further, clan land can be in dispersed portions not necessarily, or even not often, in contiguous bounded clan territories. In other words, clans are not territorial units.

While land ownership is inherited based on patrilineal descent, there is considerable flexibility in practice. According to (Holzknecht 1974, p. 67):

> …land use rights are interpreted in a considerably flexible way… This flexibility allows a significant number of outsiders to be brought into a group and ultimately (after one, two or three generations) to be fully incorporated into it.

This flexibility is a common feature of social organisation in the RMV. Our research and the field experience of partner researchers confirm that social norms and practices regarding land rights, division of labour according to gender, and clan leadership are negotiated and interpreted flexibly.

Clans come together for ceremonies and for defence, but traditionally not as economic units. In the RMV, there is little evidence of clans operating collectively for any form of landscape-wide development of clan resources. Holzknecht (1974, p. 67) mentions that "some subsistence crops require a greater investment of time and labour than others and so are conducive to group participation in their growth cycle". Such group activity does not occur at the clan level, but involves smaller groups of close kin.

Clan leaders in the RMV, as is most common in PNG, are not government appointed. The role is not usually hereditary. Leadership is achieved on the basis of the prestige of individuals, often, but not always, recognised by consensus. Importantly there may be several people who are regarded as clan leaders, but when this is the case, they do not act as a formal committee. Indeed, there may be factional opponents within the clan leadership. The informal nature of clan leadership has important implications for decision-making.

3. The study sites

The study sites for this research are three villages in the grasslands in the central section of the of the RMV near Ramu township.[6] The RMV consists of two river valleys separated by nearly joined watershed boundaries in the north of PNG, between the main highlands range and the northern coastal ranges (the Finisterre Range). The valley floor is dominated by anthropogenic grasslands of kunai grass (***Imperata** cylindrica)* and the residual rainforest on surrounding hills is under threat from harvesting for firewood and house construction material (Mulung, 2012; Baynes et al., 2017). A significant area of the RMV is used by large agri-industrial businesses, thereby creating some formal employment opportunities, but many villagers rely on semi-subsistence gardening for their livelihoods (Errington and Gewertz, 2004; Mulung, 2012), cultivating mixed food crops in gardens scattered over the hill and valley lands. Families typically manage two or three small gardens, often much less than a hectare in size. Each garden can be used for a different purpose. Types of gardens include hill gardens, valley gardens, yam gardens and kitchen gardens (Mulung, 2012).

The common description of the economy as "subsistence agriculture" needs to be qualified as many families obtain cash income by selling surplus horticultural and other products in markets and almost all people are involved in at least small-scale market activity. Some farmers produce crops such as cacao and coffee specifically for sale. Some individuals, mainly men, work for wages outside the village, providing remittance income.

4. Methods

The project in the RMV aims to improve the grassland landscape by forest restoration and simultaneously improve local livelihoods. The research reported in this paper is a sub-set of that research. The project partner, Ramu Agri-industries Ltd, is involved in work with local people to encourage planting and restoration as part of its environmental obligations and social responsibility policies. Since the first phase, the focus has moved from an emphasis on forestry by clan and multi-clan communities towards agroforestry at the family level. This paper includes the specific findings of the study combined with the findings of other studies undertaken by the project and, perhaps more importantly, the intensive local knowledge of the co-authors, two of whom are employed by the local partner.

To ascertain the factors influencing land-use decisions in the RMV, we investigated farmers' perceptions on tree planting, current land use, farming practices and preferences, and decision-making regarding growing trees for landscape restoration.

To ensure reliability of data, we gathered and corroborated empirical data from several sources. We carried out individual and group interviews with clan members as well as clan leaders from each of the case study villages. To accommodate gender specific viewpoints, we interviewed women and men separately. The interviews were carried out in two stages, in October 2018 and October-November 2019. All individual and group interviews were carried out under the approved ethics protocol.[7]

We used semi-structured interviews focusing on four broad topics:

- Topic 1: Perception of women and men on tree planting within the landscape
- This focused on investigating opinions about planting more trees and the scale of planting within the landscape.
- Topic 2: The typical current family farming system
- This focused on identifying types and locations of gardens and the types of crops grown in each. It also examined responsibilities of women and men in gardening.
- Topic 3: Preferences of women and men regarding the purposes, location and patterns of tree planting

[6] The names of the villages are not given in order to preserve confidentiality.

[7] The research was undertaken under ethics approval from the Human Research Ethics Committee at the University of the Sunshine Coast (approval number S171139 for ACIAR project FST/2004/050). A Research Participant Information Sheet was prepared in *tok pisin* (the local language) and the contents explained to potential participants. Participants were informed that participation was entirely voluntary and consent could be withdrawn at any time. They were also informed that individuals would not be identifiable by non-members of the research team or in any reports or publications.

- This focused on the opinions of women and men on the purposes and benefits of planting more trees in their gardens; their preferences on types of trees, and preferred locations; cropping patterns for planting trees; and challenges of planting more trees.
- Topic 4: Decision-making on land use management by families and clans
- This focused on decision-making at family and clan levels on land use and tree planting, including the process of decision-making. There was also a focus on understanding the involvement of women in decision-making at family and clan levels.

To ensure consistency between the topics covered in the semi-structured interviews, we used a checklist of key points for interviews based on these topics (Appendix 1). Each interview focused on different questions depending on which group of stakeholders were being interviewed. Interviews with individual farmers investigated all four topics. Interviews with leaders and elders mainly explored topics 1 and 4. Women's group interviews specifically aimed at collecting data for topics 1, 3 and 4. The interview process was undertaken in a flexible manner and additional questions were added or questions were omitted depending on interviewee responses and circumstances.

The first author initiated the interviews in English. Questions were translated by two of the co-authors (NW and MT) who were involved in the interviews. Interviews were not recorded, but detailed notes were kept.[8]

Villages were informed before visits took place to ensure that timing was convenient and that villagers would be available for interviews and other activities. Informal interviews were conducted in conjunction with activities conducted by the partner organisation's field staff. Sampling was purposive and involved snowball sampling, in which one interviewee suggested other appropriate interviewees. We also undertook opportunistic casual interviews with villagers on occasion, such as while visiting gardens and monitoring the setting up of tree nurseries by pilot families of the project.

In total, we conducted eighteen individual interviews with farmers (seven women and eleven men). We interviewed four clan leaders separately. At group level, we also conducted three group interviews: one with women; one with leaders and elders; and one with farmers (mixed men and women) who were from the pilot families setting up tree nurseries supported by the project.

The sizes of the different sub-samples were not defined in advance as the aim of the research was to identify the variety of views held by different types of informants about the four topics, not to quantify the frequency with which each view was held. Interviewing ceased when the research team judged that data saturation had been achieved. This was determined when no new opinions were presented and the opinions expressed repeated previous statements.

Qualitative data were analysed according to the following process. First, we extracted the key messages from all interviews to identify any common views. Second, we searched for patterns and emerging themes. Lastly, we reported the results of all interviews based on each theme and used the evidence gained from other methods to corroborate our results.

We also undertook visualisation exercises in which men and women were asked to draw a vision of how they would like their gardens to be in the future. Visualisation exercises stimulate participants to depict the future as they would like it to be, and this indicates their motivation for courses of action (Boedhihartono and Sayer, 2012) and for drawing a long-term vision and pathways for development in the future.

The visualisation exercises were carried out separately by women and men focusing on two identified scenarios, one at a landscape scale and the second at the scale of individual farm plots. For the first scenario, we organised villagers into separate groups of men and women (4–8 in each group). There were eight men's groups and four women's groups. Each group was asked to discuss the landscape that they wanted to see in the next 5–10 years and prepare a drawing illustrating the results. We received a total of 13 landscape drawings (eight from men's groups and five from women's groups) from the three villages.

For the second scenario (on the farm scale), we conducted the exercise in two villages asking individual farmers (women and men), working separately to illustrate the preferred patterns for tree growing. We obtained eleven drawings from men and ten from women.

5. Results

We sorted the information provided to identify emerging themes. The four emerging themes largely arose from the four topics discussed in Section 4. However, the data obtained led the findings to be classified somewhat differently for analysis.

In interviews, the *tok pisin* word *diwai* was used for tree. The word *diwai* is locally understood to mean trees other than fruit trees (Kagl et al., 2019). It usually does not include fruit trees or trees such as cacao or coffee plants as trees, unless specified by the questioner. In the following discussion and in informants' quotes, we use "tree" or *diwai* to refer to trees other than fruit trees, cacao and coffee unless otherwise qualified.

5.1. Theme 1: Perceptions of the benefits and functions of tree planting

Regarding the benefits of growing trees, we found that gardening and land use are still practiced in traditional ways for largely subsistence agriculture, with some sale of surplus. Each family has multiple gardens and in different gardens they cultivate different crops and trees (including *diwai* and fruit trees) for different benefits. For example, home gardens are located near houses for growing food crops with fruit trees. Gardens near the creeks are used for cash crops (e.g., cacao) and for banana, taro and shade trees. Gardens in grassland areas are for staple crops (e.g., yam and sweet potato), with fewer *diwai* or fruit trees grown.

Both *diwai* and fruit trees are used for a variety of purposes. The interviews revealed that farmers grew them for household use and for shading crops when they moved to a new settlement.

> We moved from the big hamlet to settle in this area. At first our family members started to plant many fruit trees and diwai to improve conditions in the area and for food supplies such as coconut, mango and others. (Farmer no.14, M)

One male farmer provided some details about how trees are used for housing construction:

> The poles and posts for houses are usually made from diwai and coconut trees. A traditional roof can be made with kunai grass and the leaves of sago palm, and the walls of a house could be constructed with bamboo, pit-pit, and coconut fronds. (Farmer no.17, M)

We asked about reasons for planting trees in the future. Some farmers expressed concern about the scarcity of *diwai* for housing construction, motivating them to plant more *diwai* on their land. One male farmer and a women's group discussion mentioned their experiences of walking to the mountains for 4–5 h to get good timber for housing. This meant they took two or three months to collect the timber needed to build one house.

All interviewed farmers wanted to plant more *diwai* primarily for household use followed by planting for crop shading. A small number of farmers thought of benefits from timber sales.

The interviewees revealed that the key barriers to planting more *diwai* on their land included the risk of fire damage, lack of available seedlings and limited labour. Generally, the interviewees obtain seeds from the wild and do not have experience in establishing tree nurseries or raising seedlings, although some farmers have experience in raising

[8] Where informants are quoted in this paper, the quotes are based on these notes, but the quotes are not necessarily strictly verbatim.

Table 2
Preferences on small-scale planting for landscape configuration.

No.	Quotes
1.	*Because of population increases day by day, we need to manage and spare the land for the next generation, so, the use of land is allowed for a subsistence purpose of cultivation/plantation on a certain size plot.* (Leader speaking in group interview. M.)
2.	*If someone wanted to plant diwai in a large area of clan land, it would be against [traditional] rules for the uses of clan land.* (Leader/Elder no.03, M)
3	*I prefer diwai to be grown bit by bit and in a gradual change, not over the whole area.* (A woman participant in a group interview)

seedlings without nursery training. Hence, when they had opportunities to attend nursery training programs, they were positive about applying the knowledge.

> I had never raised seedlings or set up a nursery before. After I was trained [by the project], I tried to adapt and improvised my own nursery. I used available materials to build a nursery house by starting step by step from what I learned, collecting seeds, setting up the nursery and continuing until I got results. (Farmer no.03, M)

Beside the benefits of trees for household uses, one third of all individual farmer interviewees (six of eighteen) mentioned awareness of the importance of growing trees (including *diwai* and fruit trees) for environmental purposes, but most limited environmental concerns to those related directly to their living conditions. For example, they were aware that tree planting is good for increasing greenery, improving soil condition, protecting against landslides and flooding, and providing windbreaks.

In summary, farmers recognized the value of planting trees (including *diwai* and fruit trees) for multiple purposes and primarily to generate livelihood benefits associated with daily living, particularly to ensure food security and improve crop production and management.

5.2. *Theme 2: Landscape configuration and land use preferences for tree planting*

5.2.1. *Scale of tree planting*

The results of all individual interviews indicated the preference for small-scale tree planting on clan lands and reserving space for gardening and food crop cultivation (Table 2). The results from the interviews with the clan leaders provided information on traditions influencing the scale of planting. Clan leaders particularly commented that *diwai* planting on a large-scale may not be acceptable to clan customs and may create conflict over land use.

5.2.2. *Preferred locations for tree planting*

According to the results of individual interviews, RMV farmers preferred planting *diwai* in cash crop plots (e.g., cacao, vanilla), in home gardens and in varied locations within the village where wood for construction would be available to replace houses.

Two-thirds of all male respondents expressed strong support for some species of *diwai* needed for shading crops such as cacao. One farmer said:

> I planted cacao before but without good shading, so the sun destroyed those cacao trees… I am planning to plant diwai to provide better shade than in the previous cacao crop. (Farmer no.10, M)

Women's preferences were diverse because they usually contributed labour to all crops grown by families. However, most women preferred planting *diwai* and fruit trees near houses and in home gardens for easy access and for use as housing materials and food supplies. In addition, participants in a women's group discussion said that they would like to grow *diwai* near their houses, so their husbands would not need to travel far to get timber for housing.

Table 3
Preferences against mono-crop tree planting.

No.	Quotes
1.	*It is fine to grow trees in either food crop gardens and in cacao crop for shading, but I do not totally agree to with a mono-crop tree plantation and if my husband practiced this pattern, I would not agree and would not support this.* (Farmer no.08, F)
2.	*It would not be good to practice monoculture tree plantation. A good way to grow trees is to mix with other crops, which give various benefits for the family, particularly for food supplies.* (A male participant, Group no.3, M&F)

Fig. 1. Preferred landscape drawn by a women's group showing lands allocated to cash crops (e.g., cacao) with shade trees (A), fruit trees and *diwai* (B) and food crops (C).

Fig. 2. Future landscape scenario by a men's group showing their priority areas for growing *diwai* in cash crop plots (cacao) (A), surrounding houses (B), and home gardens (C).

> I intend to plant the seedlings and plant them near my house, and then we will not need to travel far to get timber for housing as in the past. (Farmer no.05, F)

Most women did not want trees growing in all gardens, because they perceived that growing many *diwai* might negatively affect the staple crops that they mainly managed.

5.2.3. *Preferred patterns for tree planting in gardens*

The informants identified patterns for integrating trees (including *diwai* and fruit trees) into their gardens. The possible patterns of tree planting to be adopted needed to fit in with existing practices and would not require high investment. Some farmers preferred to grow trees mixed with a variety of food crops for multiple benefits such as *diwai* for house construction, and fruit trees and vegetables for food and income. Others focused on planting in alternate rows of *diwai* with cash crops (e.g., cacao and vanilla) for shade.

The different preferences were often related to gender, because men

Fig. 3. Preferred landscape by a men's group showing the need of maintain kunai grassland in the future.

Fig. 4. Landscape scenario by a women's group showing the preferred location for *diwai* and fruit trees growing surrounding houses (A) and in home gardens (B).

Table 4
Involvement of women in land use decision-making within families.

No.	Quotes
1.	*Cacao is grown for income, so both husband and wife discuss to make decisions. For instance, cacao crops need more space. If it is necessary to extend to use their other garden areas, it requires husband and wife to talk about this land use change.* (A summary of the experiences of some participants in a women's group discussion.)
2.	*I can freely make decisions for the gardens that I am mainly responsible for, and I also contribute my views to my husband for cacao planting such as growing trees and spacing.* (Farmer no.08, F)
3.	*My husband is busy working with RAIL. Mainly, I take care of our family's gardens but consult with my husband for final decisions on crop management.* (Farmer no.02, F)

and women frequently have different priorities on locations and patterns of tree planting.

Mono-crop tree planting was not generally preferred as we learned from both individual interviews and group interviews (Table 3). However, one male participant in the mixed group interview supported the possibility of mono-culture tree planting. He said that growing large number of *diwai* would help to generate income for families from selling timber if markets for timber existed.

Results of visualisation exercises showed the same preferences for small-scale planting of *diwai* in the three priority areas (Figs. 1 and 2). However, a reflection from the drawing of one men's group illustrated grasslands to be maintained in the future for hunting (Fig. 3).

Overall, farmers did not envision tree planting on a large scale across the landscape. They preferred planting on a small-scale in line with existing practice. They also considered that the clan land should not be fully utilised, but rather that space should be reserved for future use.

5.3. Theme 3: Gender and preferences for tree planting

5.3.1. Gender division of tasks and farming practices

Interviewees noted the roles of men and women and the division of labour in different gardens according to gender. Two-thirds of interviewees defined work with specific crops as the tasks of men or women. For example, women worked on household chores and would oversee the food crops and staple crops. Men focused on earning cash income including cash crop cultivation, and on house construction and hunting. In some families, men and women worked together on all crops and other families had women taking the main responsibilities because men had off-farm jobs. It is important to note that the division of labour by gender is a general pattern but varies according to family circumstances. One woman explained the division of tasks in her family:

> I mostly manage all gardens for our family because my husband works in a mining site in another province. I could not be a permanent employee, because of the workload at home. (Farmer no.11, F)

5.3.2. Involvement of men and women in decision-making

The interviewees indicated that land use decisions at the family level aim to maintain land claims and to sustain livelihoods, particularly for crop cultivation. The results of all interviews showed that both men and women are involved in land use decision-making at the family level, but this occurred in slightly different ways in different families (Table 4). Two common practices were found. The first practice involved men and women jointly making decisions about crop management and the uses of land for gardening. Both men and women discuss issues if they are related to income. The second pattern involves women making decisions about crops that they are responsible for, although their decision-making role was generally not the same as that of men. Some women could freely decide any practices by themselves over their identified gardens. In some families where men have off-farm jobs, women took care of crops and made day-to-day decisions about crop management, but they consulted with their husbands about final decisions.

Women's involvement in decision-making at clan level was limited. It was obvious that male members held a very high level of decision-making power. For example, according to observations in project meetings and consultations, male clan leaders, elderly male clan members and educated male clan members, usually dominated negotiations. Although women participated in these meetings, they were mainly observers and sat in the outer circle of discussion, although they supported the agreements finalised by the men.

However, overgeneralisation about the dominance of men in decision-making on land use matters is unreliable. Separate research within the project (Thom et al., 2019), showed that women sometimes undertook different roles. For example, in one case a woman was nominated by a man to be deputy chair of an Incorporated Land Group (ILG)[9] and was elected. This shows that women are not automatically excluded from formal decision making. In another case, when a trial plot was negotiated between a male farmer and the project, women decided the plot was too large and required too much work, so they developed a smaller plot. In this case:

> … women exercised their power simply by deciding what work to do ("voting with their feet"). This seems to have been accepted by the male. This illustrates that women can exercise significant "informal" power, simply by ignoring or modifying more formal decisions.
>
> (Thom et al., 2019)

[9] See Section 6 for further detail.

Fig. 5. Landscape scenario by a men's group indicating a preference for growing *diwai* with cash crops e.g., cacao (A) and *diwai* on a mountain slope (B).

Fig. 6. A scenario of farming patterns for tree growing by an individual man focused on inter-cropping in cash crop gardens (A and B).

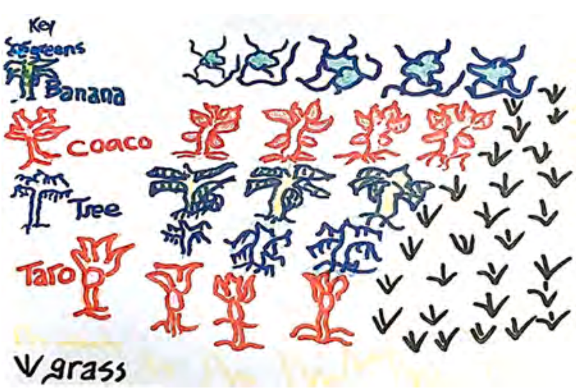

Fig. 7. A scenario of farming patterns for tree growing by an individual woman illustrating *diwai* growing mixed with food crops (e.g., green vegetable, banana, taro) in home gardens.

5.3.3. *Preferences of men and women for cropping patterns in tree planting*

Men and women often preferred different cropping patterns. In individual interviews, most men wanted to grow *diwai* in rows as shade for their cash crops. Women preferred to plant both *diwai* and fruit trees in mixed fields with their food crops (but not in rows). The results of landscape visualisation exercises gave similar evidence on gendered preferences as evidence from the interviews. Women and men prioritized different areas and patterns for growing *diwai.* (Figs. 4 and 5).

The visualisation exercises of the preferred farm patterns, done separately by individual farmers, are examples of different preferences held by an individual man and an individual woman. (Figs. 6 and 7).

Table 5
Scenarios for obtaining permission for tree planting from clans.

No.	Quotes
1.	*If any families want to ask for more land from the clan for tree planting, they may put a request for planting diwai mixed with other crops for subsistence living purpose. Diwai should be planted at a certain and small-scale for family consumption, not in a large area.* (Group No 1, M)
2.	*The clan would check about the intention of this planting. In case the person intends to use a large area for growing diwai for economic purposes, clan leaders would discuss and negotiate, to perhaps gain a share of benefits from that plantation.* (Leader/Elder no. 03, M).

5.4. *Theme 4: The role of clans in land use decision-making*

In this research we have been particularly concerned with the role of tenure in land use decision-making and governance in FLR. Although tenure is recognised as important for FLR in the literature (see Section 1), it is not always dealt with in depth. McLain et al. (2021), following a review of Restoration Opportunities Assessment Methodology (ROAM) reports from eight countries conclude "that tenure and land governance were not analyzed in a more substantive fashion" (McLain et al., 2021: 10).

Participation and decision-making about large-scale tree planting initiatives are part of customary land tenure practice. For outsiders to engage with activities related to land use requires agreement by the clan. For example, the project needed to inform and consult with the clan leaders to obtain permission to implement tree planting initiatives even with individual clan members, because their activities could alter the use of the clan land and tree planting could be interpreted as having a commercial purpose. Consultation meetings and negotiation processes were organised between the project team and the clan leaders. In two cases, the agreement was formalised with the signing of a *Clan Land Usage Agreement (CLUA),* an instrument commonly used by commercial companies to give visible evidence of clan support. Although it is not required and not a universal practice, it might be interpreted as an emerging new customary practice.[10] Under these two agreements, the targeted clans agreed to operate tree nurseries and tree planting at a family level, not at clan level.

We sought examples from clan leaders to learn about the process of obtaining permission for tree planting (Table 5). Negotiations about permission for non-standard land use often involved senior male kin in discussion with clan leaders, who have the right to review the purposes of planting of *diwai* by families for some specific purpose.

It is important to stress that the process of obtaining clan approval is not about getting the approval of clan leaders as some sort of committee. Instead, it is essentially an informal process of obtaining support through negotiations. In this context, decisions are made according to broadly accepted, although flexibly interpreted practices.

6. Discussion

This section does not test the situation in the RMV against the various sets of FLR principles, but uses some of the principles as a heuristic device to frame discussion.

There are several crucial aspects of FLR presented in the six principles of Besseau et al. (2018) and the related literature, which are useful for understanding what FLR looks like, or could look like, in the RMV. These aspects are the focus on entire landscapes (landscape scale), stakeholder engagement and participatory governance, multiple benefits and functions, and the mosaic nature of landscapes under FLR.

The focus on entire landscapes or landscape scale is illusive in the

[10] CLUAs are recognised by the Lands Department and CLUAs are also used as an official document when accessing funds from superannuation for construction/maintenance of housing on traditional/customary land.

case of the RMV. This needs to be discussed in the context of the general difficulty in defining or identifying landscapes. According to Maginnis et al., (2004, pp. 331) a landscape is “a contiguous area, intermediate in size between an ‘ecoregion’ and a ‘site’, with a specific set of ecological, cultural and socioeconomic characteristics distinct from its neighbours”. This definition was written from the perspective of a conservation organisation. Maginnis et al. (2004) make it clear that landscapes are determined from the perspective of different stakeholders.

It is clear that defining a particular landscape is not an objective process. The landscape is a social construction (Fisher et al., 2008) and the boundaries are identified according to the intentions of different stakeholders. However, a key point is that landscapes are understood as consisting of a scale larger than individual sites.

In the case of the central portion of the RMV it is extremely difficult to find a basis for drawing landscape boundaries that are relevant to clans or households. The central portion of the RMV consists of a riverine plain dominated by grasslands bordered to the north and south by mountain ranges with some forests, but largely deforested. There are multiple and overlapping landscapes, depending on the perspective of various stakeholders. On the social and geographical levels, clan members and clan lands are spatially dispersed and often intermingled with other clan members and clan lands. On the administrative level, local government consists of Local Government Units (LGUs), but their administrative boundaries do not correspond with clan lands or clan membership. Theoretically at least, the provincial or national government may have an interest in a landscape in terms of achieving objectives related to biodiversity conservation or water supply, for example. The challenge would be to translate these provincial or national aims into practical action when the clan-based system does not enable a landscape approach. In practice, provincial and national level planning currently has very little impact at local level land use planning in the RMV, although this may change.[11]

According to Mansourian (2016), the focus on participatory governance should be taken to mean the involvement of affected people (among other stakeholders) in decision-making about land use, but many projects do not implement this in an effective manner. An implication of this is that, if participation in decision-making is to be meaningful, landscape interventions need to be negotiated rather than planned (Fisher et al., 2008).

In the RMV there is no institution (traditional or government) that makes effective land use decisions beyond the level of clan land. The government does not control land use on clan land.[12] There are significant portions of land held under lease used for agribusiness or commercial plantations, but these are not part of an overall administrative plan. Clans decide on allocation of land to clan members and can enable or prevent new forms of land use, but they are not actively involved in broader landscape level land use activities. In any case, individual clans cannot make decisions on the lands of other clans intermixed with their own lands. While clans, as institutions, do make land use decisions relevant to tree planting, they do not and cannot make decisions about large contiguous territories as clan lands and clan membership tend to be in dispersed packages.

Under legislation there is a provision for Incorporated Land Groups (ILGs).[13] These are legally recognised bodies which represent clan members and sometimes the members of multiple clans for the purpose of making contracts about the use of clan land with commercial organisations such as mining or forestry companies. Not all clans in the RMV are formed into ILGs. The ILGs do not generally make land use decisions, apart from such contracts. They are largely concerned with allowing outside access to groups not much interested in conservation as such. ILGs do not control large contiguous territories. Instead, any authority they have is limited to the territories held by their member clans. They are, therefore, not institutions able to coordinate landscape scale land use planning on their own, although they could potentially play a role in landscape level land use planning with other relevant stakeholders such as government or other ILGs. At present, they do not do so in the RMV.

The point here is that, whatever boundaries are defined for a landscape, there is currently no institution with the authority or capacity to carry out landscape scale planning or negotiation. As we have shown, the negotiation or planning takes place at the clan, sub-clan or family level and these relate to small often dispersed packages of land, not whole landscapes.

Our research has shown that land use decisions are made by individual farmers subject to the agreement of the clan when concerns are raised about new types of land use (such as commercial crops) and large-scale planting. This is consistent with the findings of Baynes et al. (2017) and Mulung (2012). In our research, most, but not all, choices by individual farmers were relatively unproblematic in terms of land use being acceptable to the clan. We also found that some informants were against large-scale planting of trees because of the need to preserve land for the use of the growing population.

The findings highlight another factor that limits widespread tree plantation in the RMV. The research did not reveal any concern with conservation as an abstract value. For example, there was no specific expression of concern with biodiversity. Although interviewees did recognise the environmental benefits of planting trees, the benefits identified were limited to direct benefits to their living conditions such as improving soil and landslide and flood protection rather than more generic environmental benefits. This suggests that lack of interest in the conservation benefits associated with FLR may be a major factor in large scale planting and action at the landscape level in the RMV.

Martin et al. (2021), in a review of tree planting across multiple countries, noted that planting focused on utilitarian species rather than decisions made for primarily conservation reasons. In a study of tree planting activity by farmers in various parts of Indonesia, Kallio et al. (2011) reported that farmers’ reasons for tree planting related to household use and income rather than environmental reasons. This is very similar to our research findings.

The findings about women’s preferences about cropping mixes and their roles in decision-making differing from those of men is not novel. Similar findings have been reported elsewhere, such as by Kiptot (2015) on various countries in Africa and Singh et al. (2016) on Rajasthan in northern India. The point of noting these findings in reference to the RMV is not to show that they are in any way surprising, but to emphasise that women in this patrilineal society do play a role in land use decision-making relevant to FLR. This is an important factor in the household-centred nature of land use decision-making.

Given the nature of land tenure and decision-making, the land use is very much in the form of small-scale users forming a multifunctional mosaic pattern across the landscape. Individual families generally have several small plots in different locations used for different purposes. The plots contain a wide range of different species and provide a range of different benefits including food, building materials, shading for mixed crops and cash income. The visualisation illustrated by RMV farmers confirmed preferences for continuing the diversity of land use practices. Their preferences favoured agroforestry practices, which can be a potential intervention for landscape restoration in the RMV.

While FLR in the RMV does not reflect the image of landscapes planned or negotiated on a large scale, it is consistent with the point presented by Maginnis and Jackson (2005, p. 19), that FLR does not

[11] This may change if government interests in other forms of land use, such as conservation, change. The central RMV does not have Wildlife Management Areas/Conservation Areas. In other parts of PNG, including in other parts of Morobe and Madang provinces, provincial and national level planning may occur in such areas.

[12] The Forest Authority does have authority over commercial timber harvesting and associated royalties under the Forest Act, but this has little relevance in the study area.

[13] Formed under the Land Groups Incorporation Act (1974, subsequently amended 2009),

have to "be applied on a large scale, but rather that site-level decisions need to be made within a landscape context". This finding is similar to the findings of the study by Baynes et al. (2017) which confirmed the potential of small-scale planting as a way to achieve landscape restoration in the RMV.

Based on our research, we argue that ecological functionality can be achieved at small-scale by large numbers of families planting small-scale mixed plantings of trees and horticultural crops. However, we question whether large-scale landscape restoration as often envisaged by the FLR movement can be achieved or meets the expressed needs of farmers in the RMV.

Sayer et al. (2015) identify ten "pre-conditions" for FLR. They make important observations that effectively highlight ways in which the common notions of what FLR might look like differ from our interpretation of potential FLR in the RMV. Based on a review of seven landscapes in various countries, they conclude that:

> The ideal situation where the outcome of a comprehensive landscape approach would be widely accepted and translated into an enforceable spatial plan does not exist amongst the seven landscapes we reviewed. (Sayer et al., 2015, p.8.).

The implication here is that an agreed spatial map of a whole landscape is what is commonly accepted from FLR. The situation we envisage for the RMV is that FLR, if it develops on a larger scale, would not look like that. It would not be planned or coordinated but would consist of a large number of individual plots, based on individual decisions, that in effect contribute to the landscape services associated with FLR.

7. Conclusions and implications

A major conclusion from this research is that there are currently no landscape level institutions in the RMV which have the capacity or mandate to coordinate landscape level land use planning. This may change with more active engagement of government or other actors in land use planning. Further, clans may take on new roles. Baynes et al. (2017) identifies the importance of social capital in developing capacity for landscape level planning. It seems possible that building social capital between clans may have potential for collaborative planning by multiple clans at the landscape level.

One policy implication is that the implementation of forestry extension services in the RMV might be useful in facilitating this process. The presence of forestry extension services at a local level would enable regular contact with clans and would possibly support negotiations between clans leading to cooperation in forest restoration activities on a larger scale, such as plantations for micro-watershed protection on clan boundaries. This would not, however, be likely to impact on the individual land use decisions by individual farmers who make decisions about their own gardens.

A challenge is that forestry extension services are lacking in the RMV and PNG more broadly. The need for extension services has been noted by previous studies (Mulung, 2012; Holzknecht, 2014; Baynes et al., 2017). Extension advice is needed in fields such as nursery establishment and management, seedling production and species selection. On a pilot basis, some services have been provided by RAIL and the series of ACIAR projects to a small number of villages, but these have not reached large numbers of farmers and operate on a small geographical scale. There is no comprehensive government forestry extension service in PNG at present and no clear extension policy, although individual field officers provide extension advice and there are some nurseries that provide seedlings. It is fair to say that the main focus of the Papua New Guinea Forest Authority (PNGFA) is on commercial forestry (logging) and protected areas, with increasing interests in climate change. However, commercial forestry is not a major activity in the central RMV.

Development of extension services would support small-scale tree planting for FLR in the RMV and in PNG more broadly, especially by assisting with tree nursery development and training.

While provision of extension services is a potential policy option at the local level, the severe financial challenges currently faced by the PNG government make provision of such services on anything but a very small scale unlikely in the near future.

Some aspects of the RMV experiences may have implications elsewhere in Melanesia, where a number of countries have broadly similar tenure systems. Nevertheless, regarding policy implications for FLR at regional/international levels, it is important to recognise that FLR is not guided by fixed policy per se. It is generally implemented at project level, with varying levels of support by national governments. FLR projects and programs are supported by sets of broadly accepted guidelines applied by various agencies with often differing approaches. For this reason, there is no obvious scope for recommending policy, except by influencing approaches taken by different implementors by identifying some methodological implications and providing useful insights.

The research described in this paper has presented a case for the importance of local context, especially the social and cultural context, in applying landscape restoration. Papua New Guinea is a rare case of a country with constitutionally recognised customary land tenure which has not been largely "dismantled by the colonial powers" (Anderson, 2015, p.1). It is also unusual because the customary land, while legally recognised, is generally without registered boundaries. The unusual nature of land tenure means that landscape restoration in PNG would likely look very different from FLR elsewhere. Nevertheless, it is not intended that the assessment of factors affecting landscape restoration in the RMV can be easily generalised as a model for PNG more widely. The general picture of the clan system and tenure in the RMV is broadly similar to that elsewhere in PNG and much of Melanesia, but there are regional differences. For example, the highlands of PNG are geographically different from the RMV, agriculture is much more cash based and, while land is still mostly clan-owned, there has been a creeping privatisation of land in that region. We would also suggest that landscape restoration (called FLR or otherwise) could be quite different in parts of PNG where matrilineal tenure is practiced. Further research in different parts of PNG would identify interesting similarities and differences.

This research highlights a key point about understanding context in FLR implementation. As discussed in Section 1, the importance of context is often mentioned. The RMV case study clearly shows that context can be quite complex and that it is necessary to investigate context in detail before proceeding with detailed FLR planning. Unless the perceptions and preferences, and the reasons for these, are well understood, FLR plans may be inappropriate. Tenure, and resulting decision-making about participation in FLR, are particularly important. While it is essential to recognise that tenure in the RMV (as in PNG more broadly) is customary and clan-based, this recognition is not adequate without a deeper understanding of what type of decisions clans make, what decisions the individual clan members make and what decisions women and men make. We argue that this demonstrates the importance of establishing and understanding of context in detail as an essential preliminary step in FLR implementation, not just as a box-ticking exercise.

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Declaration of Interest

All authors have seen and approved the final version of the manuscript.

Data availability

The data that has been used is confidential.

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Appendix A

See Appendix Table A1.

Table A1
List of topics, key points and broad questions covered in the interviews.

Topics and key points for research	Broad questions covered in the interviews
1. **Perception of women and men on tree planting within their landscape** – Opinions about planting more trees – The scale of planting within the landscape	• Do you think growing more trees is good for your area? If yes, why? /if not why not? • Do you want to see tree growing to cover all clan lands? If yes, why? /if not why not?
2. **Typical current family farming system** – Types and locations of gardens – Types of crops grown in each. – Responsibilities of women and men in gardening	• Do you have trees growing on your lands? Grown naturally or planted? If planted, why did you grow them? and how? • How many gardens do you have? And what type of crops do you grow in each garden? • In your family, how do you divide farming work between men and women?
3. **Preferences of women and men on the purposes, location and patterns of tree planting** – Opinions of women and men on the purposes and benefits of planting more – Preferences of women and men on types of trees, and locations; cropping patterns for planting trees – Challenges of planting more trees	• Do you want to plant more trees in your land? If yes, why/ If not, why not? • Where do you want to plant more trees? • If you plant more trees, what would your gardens look like? • Are there any challenges for planting more trees in gardens? Is it possible to plant more tress? Why/ If not, why not?
4. **Decision-making on land-use management by families and clans** – Decision-making at family and clan levels on land use and tree planting – The involvement of women in decision-making at family and clan levels.	• How do you discuss and make decisions within your family regarding tree planting? • If any family wants to grow a greater number of trees, how do they need to inform the clan? Any examples? • What will happen if some families grow a greater number of trees without informing clan? Are there any disputes/ examples? • If a family wants to grow more trees, how are women involved in making decisions? • What will happen if a woman want to plant a greater number of trees on clan lands Any examples?

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Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valley[1]

Melinda Thom, Kanchana Wiset, Fiona Borthwick and Robert Fisher

Abstract
Efforts to implement FLR in the Ramu-Markham Valley (RMV) have increasingly focused on family or small group based activities, incorporating agroforestry. Gender issues are crucial in these activities both for practical and equity reasons. The practical reason is that even though both men and women have a key role in any agricultural activity, women provide much of the labour on a daily basis. Interventions will only be successful if women support activities, benefit from them both in the short and long term and are willing and able to provide labour. Equity is important because changes to gardening and related activities impose costs on women, both in the form of increasing labour and changes to the availability of food and forest products and the distribution of benefits from these. Society in the RMV tends to be heavily male-dominated and this is reflected in decision-making including decisions about use of resources. Nevertheless, the domination is not absolute and understanding opportunities for greater involvement of women in agriculture and agroforestry requires nuanced understanding of the women's roles and activities. This report presents results of action research by Melinda Thom, into the relationship between gender, women's labour and economic activities in the RMV, paying attention to resource rights and decision-making about resource use and benefit sharing. The work is complemented by findings of research carried out by Kanchana Wiset as part of her PhD studies and an intern's report by Émilie Tremblay. The report also provides recommendations relating to ways to incorporate gender into project activities as a cross–cutting theme.

Introduction

The Ramu-Markham Valley (RMV) contains two rivers flowing in opposite directions – the Markham to the south-east and the Ramu to the north-west. The watersheds of the two rivers are separated by modest watershed boundaries. A significant portion of the valley floor consists mainly of grasslands, with forests mainly on the slopes of mountain ranges to the south and north. The grasslands are anthropogenic and have been a critical feature for around three thousand years.

In recent years Ramu Agri Industries Limited (RAIL), in partnerships with a series of projects supported by ACIAR, have been engaged in efforts to reforest areas of the

[1] This report is a revised and expanded version of a paper presented by Melinda Thom at the International Conference Forest and Landscape Restoration: Making it happen. 25-27 February, 2019, New World Hotel, Makati (Manila). It is intended that the report will be further developed for publication after the formal end of the project.

grasslands. The ACIAR project currently working with RAIL is “Enabling Community Forestry in Papua New Guinea”. In earlier incarnations the emphasis was on working with clans to establish tree plantations. In the current project the emphasis has been on working with small groups or individual families to establish agroforestry plots. These family-based agroforestry plots need to be planned in collaboration with clans which ultimately own the land which clan members use individually for gardening and other purposes. Tree plantations and agroforestry plots are, to some extent, novel land uses and such innovations require clan agreement.

As much of the labour for gardening (which is a major element of agroforestry) is provided by women, activities will only be successful if women support activities. In addition to this practical reason for understanding gender and land use issues, gender equity issues have human rights implications. They are important because land use change affects the labour demands on women, so changes may seriously disadvantage them.

While, as the literature review will show, there is a body of literature on gender in agriculture. However, the Melanesian literature sometimes overgeneralises about aspects of gender, particularly on the gender division of labour. Even within regions and cultural groups, behaviour does not always fit abstract statements about what happens, and there are significant differences between regions. There is very little literature on agriculture, forestry and gender in the RMV.

This report has been written because experiences during the implementation of the RAIL/ACIAR project have highlighted the problems with oversimplified assumptions about the role of gender in agroforestry and forestry. The aim of the paper on which the report is based, was to present a preliminary account to what has been learned through such experiences and to reflect upon the lessons that can be drawn from them and implications for future activities.

The paper draws on the experience of staff in the joint project, PhD research (Wiset et al., 2022) and an intern’s report (Tremblay 2017). It also draws on internal project documents supplemented by published literature where relevant. Further research would be useful, but we believe that the material presented here advances the limited material available on the topic in the RMV.

Literature review

Gender studies in PNG occur in the context of significant gender inequalities between men and women. These issues are well documented in country assessments particularly the UNDPs Human Development Index (UNDP 2017). PNG scored a ‘Gender Inequality Index’ value of 0.741, giving it a ranking of 159 out of 160 countries (low ranking shows high gender inequality). This ranking is based on the low parliamentary representation of women, low secondary educational level of women compared to men, high maternal mortality rate. Female participation in the labour market is very close to male participation (69% to 70.8%) (UNDP 2017).

According to Tremblay (2017)

> PNG culture is described as discriminating against women in various ways, which is often used as an excuse not to challenge customary practices. A new financial agreement [between the European Union and the Pacific Islands Forum Secretariat] was signed in September 2017 in order to address gender inequalities and violence against women and girls in the Pacific, further indicating how these are current concerns..

Gender inequalities in PNG are described as systemic (World Bank 2012): women suffer a range of gender specific inequalities such as domestic violence, lack of access to education and health care, lack of political representation, and in many instances lack of voice in decision making from the community to the national level. Male gender inequalities are less evident in the literature but never the less must be considered in terms of increased exposure to risk, or lack of skills in some domestic areas due to constructed views of masculinity. Beyond male/female gender inequalities, consideration of non-normative issues in relation to gender is extremely limited in the PNG context, – to the point of almost complete absence. This is largely due to the legal restrictions non heteronormative individuals face. Transgender, inter-gender or queer literature is in the most part non-existent:

> Compared to many other Pacific Island societies, there is little scholarship on modern non-heteronormativity's in PNG. Nor are there any conspicuously visible and identifiable groups of non-heteronormative people in mainstream PNG life, as there are farther east in the region. (Alexeyeff et al 2014)

One aspect of gender dynamics that emerges as vital to include is that of intersectionality, in that each individual has multiple identities within a household and community that influence their experience and vulnerability (Colfer et al, 2018). This is of particular importance in a location such as RMV because of the diversity represented in these valleys. Diversity of clans, social norms, intermarriage, and power among both men and women.

Gender in agriculture and forestry in PNG

Female participation in the labour market is 69%, male is 70.8%, suggesting a somewhat equal participation in the labour market as a whole (UNDP 2017). Allen (2009), in a review of agriculture and gender in PNG, estimated that half of all agricultural labour is carried out by women and we do not challenge this estimate. There is often an assumption that women will carry out the maintenance of gardens, and men will focus on cash crops or forest crops such as cacao, coffee and timber trees, as well as labour such as forest clearing. Allen suggests that male knowledge about gardening is more limited than women's knowledge.

There is literature on gender in the RMV, but there is not much on gender in agriculture or forestry, apart from literature arguing for the importance of women in agriculture. There is little if any literature on the impacts of changed land use practices on women. Interestingly some of the studies that focus specifically on the RMV (more often on the upper Markham) make little or no reference to gender. Even Holzknecht (1974, 2014), who has written perceptively about the social organisation and agriculture, makes little explicit reference to gender issues. Read's (1950) very early account of social organisation in the Upper Markham Valley also says little about gender.

Most studies discuss gender divisions in terms of: 1. The household, where women carry out cooking, cleaning and the majority of childcare; 2. Gardening, where men have defined roles in terms of clearing, some heavy jobs (need ref) as well as some maintenance, women do much of the weeding, watering, and harvesting; and 3. Communities, where men have the majority of decision making roles and interacting with neighbouring communities. Assumptions are made about head of household always being male, but there are many instances where a woman is a head of the household.

Despite the above simplification of gender roles, empirical studies show, it is important not to make generalisations about the experiences of genders in PNG, the roles gender places in day to day life and the relationship between formal legal perspectives, local norms, and the individual lived experience. This caution is highlighted by Allen (2009). While the general conclusion is that most of the work done in gardens is carried out by women, this is not true in all contexts, clans, communities or across timescales. Having said this, this literature review highlights some of the key assumptions in relation to gender in PNG, and in relation to agro-forestry and forest landscape regeneration. In our analysis, we show where some of this work can be challenged.

Experiences of gender in agriculture and forestry in the Ramu-Markham Valley.

Land Tenure

Ninety-seven percent land in PNG is customarily owned by clans. Land based decisions are based on the magnitude of intended land use. If decisions are to be made on a larger landscape the clan will have an immense deliberation on this matter. If smaller landscape decisions are to be made in terms of the surrounding garden areas or within the vicinity of family homes then it is an individual or family based decision making process. These decisions are mostly dominated by the male members of the clan and or family. This is because land use rights are inherited through the male child in a family. For example, in the Markham Valley, a portion of land referred to as *buafump* is a land that would have clear use rights. *Buafump*, in the local dialect, means that where the ancestors have planted, one should remain on that land. An informant stated that women do have user rights until when they are married and move to their husbands' *buafump*. Widows can return back to the village and still have rights over the *buafump*. These scenarios are dependent on the woman's relationships with in-laws and brothers, leading them to be reliant on familial networks.

There are interesting cases of women who have actually gone against the assumed norms of a male dominated society. For example, in one village in the RMV, a widow who returned to her village is recognized as a prominent leader, church leader and a politician. She also is observed to have use rights over land within her clan. It was also observed that because of her status in the village, she would meaningfully participate in discussions around land usage and at times can influence decisions made. This case shows that gender norms are complex and dynamic in this region. However, it must be noted that her status is strongly linked to the status of her father which gives her certain exemptions from local norms. Her sister also married outside has moved back to the village with her sons and husband and are using land that their mother has rights over. This is a reflection that regardless of land being clan owned and use decided by men man, women do have rights that can be passed down to their sons. The implications of such can result in conflicts in benefit sharing in future projects that have economic benefits as such benefits are distributed among the male lineage.

Another example is the case of a local woman who had returned to her home village with her husband who is from another province. They have both been given user rights to plant trees for sale and planted in a larger area than expected. This has brought about conflicts within the family. The case clearly shows that customary laws are not always clearly defined or strictly enforced. They can be amended to fit situations. This can reflect the importance of proper negotiations before projects are implemented with impacts and benefits clearly explained and understood.

It is also observed that in most cases, regardless of the user rights, most discussions and decisions are made on behalf of the female with user rights. Again, her relationship with her male relatives will determine the level to which she is party to the decision-making process.

Division of Labour

In most parts of PNG, men and women work together in their gardens, sharing almost all of the labour and the contribution of knowledge and skills (Allen, 2009). Usually with the help of other family members, the male members would take on the heavier tasks such as land preparation while women would take on the lighter tasks such as planting, daily upkeep and harvest. The management of the garden through to harvesting in the RMV is usually done by women.

Within households women in the RMV take on the majority of domestic tasks such as childcare, cooking, cleaning, again men are mainly in charge of heavy labor such as house building and maintenance as well as negotiating with neighbors.

Even though women are willing to work on agro–forestry activities, their full participation is dependent on the scale of the activity.

As Tremblay (2017) has reported:

> Few suggested that an agroforestry activity on a smaller scale can be integrated into their daily chores. A larger scale agroforestry activity will increase their workload where they will be forced to prioritize thus this activity can be entirely neglected.

Generally, women are expected to be able to ensure that the daily needs of their household are met. Should extra workload be seen to make her not to meet her family’s needs on a daily basis, a woman can be seen as a wife not capable of providing for and looking after her immediate family.

Gender roles and responsibilities are quite distinctive and both men and women are expected to ensure that they do their roles accordingly.

Decision Making

Women’s participation in decision making can vary depending on the various issues. As stated above, at the family level, though the decision would be made by the male members of the family, a woman can easily influence the decision as she would be dealing with immediate members of her family. This is different at the clan level where extended male members of the family and clan decide. Women sometimes believe to participate in the decision making by agreeing to the decisions made but that can either be a genuine agreement if she has involved in parts of the process or it can also be that she is required to agree regardless of her understanding basing her trust that the decisions are in the best interest of her family or clan.

Lack of access to resources, information and knowledge can limit women’s capacity to take part in the decision either at the clan level or family level. Therefore, it is imperative to ensure that women participate meaningfully in entry meetings of agro-forestry projects.

It is important to note that women’s role in decision-making at clan level and household level are quite different. This issue is explored in some detail in Wiset et al. 2022. In the RMV clans rarely engage in economic activities (such as gardening and food production). Their main decision-making role relates to allocating land to clan members. The clan members are male as clan membership is based on patrilineal kinship. Decision-making about gardening and food production are made at the household level.

It was observed that women members of an executive committee of an Incorporated Land Group (ILG), which may be formed to assist clans to negotiate with businesses, do not necessarily see themselves as active members of the committee. For example, when attending and observing a certain ILG meeting, women representatives were observed to be vocal in the meeting but more so speaking as a general member of the ILG rather than a member of the executive committee. We suggest that this can be a result of lack of consultation by male members of the committee with the women and that decisions reached during executive meetings were done without the knowledge and participation of women. Having women as executive members of the committee can sometimes only be to ensure that certain requirements of an institution are met. On a positive note, it gives the women power to ensure that whoever they vote to represent them in such meetings can be able to voice their concern.

Other examples include women who are involved in smallholder blocks of Oil Palm where portions of land are divided amongst all the children. It is observed in meetings with smallholders that women who own smallholder blocks are outspoken. The can be a result of them being empowered enough to speak with other male smallholders. Even though the percentage is very low compared to male smallholders, there are a number of women own smallholder oil palm blocks.

It can be noted that education plays an important role in empowering women enough to be able to participate in the decision-making process.

It is important to note that formal decision-making power is not the only way women can influence land-use decision-making. A plan was negotiated by the project and a clan member (in project phase 1) for an agroforestry plot. The plot was supposed to be one hectare in area. When the plot was established the area was much smaller as the women who did the work decided they were not able to carry out so much extra labour. The women exercised their power simply by deciding what work to do (“*voting with their feet*”). This seems to have been accepted by the male land owner. This illustrates that women can exercise significant “informal” power, simply by ignoring or modifying more formal decisions.

Women’s preferences regarding trees and services from trees in agroforesty

An internal project report (Kagl et al, 2018) examined the preferences of women and men in two villages for services from family-based agroforestry. Although the results are not comprehensive, there were some useful general findings. Overall:

> Both male and female members described their needs and benefits to be derived from the different trees and, importantly, preferred local species. They also expressed interest in mixed species. The women requested fruit and medicinal trees for marketing and family consumption. The most repeated need during the interviews was for both male and female was for the trees to be used for house construction. Other needs included and highlighted were medicinal plants, fruits, nuts and fuel (firewood & charcoal).

Some findings were particularly relevant to labour demands on women:

- “Women (from both landscapes) expressed the importance of plots not being too large as that would lead to increased work for them.”
- “Women also expressed a strong preference for plots to be located close to their houses.”

Similarly, Wiset et al. (2022) found that women tend to have different preferences from those of men regardingplanting patterns, including a preference for planting trees near their houses and in home gardens. Their interests tended to be more focused on crops, including trees, for domestic use rather than for sale.

Exposure to Risks and hazards

Agro-forestry activities such as the creation of tree nurseries or new plantations in the RMV may expose men and women to risks and hazards and some have a gender bias. For women, a nursery, or planation far from the garden, or a large plantation would increase workloads and the need to carry water. Even after activities have been negotiated and initiated, issues may emerge. In the case of one village, agreements were made to establish agroforestry on a one hectare plot. However, eventually much smaller plots were prepared, because the labour demands on women preparing the larger plots were prohibitive.

If the nursery or planation is on disputed land or on boundary land this could increase exposure to violence. For men, activities on a separate plot of land, on land where ownership or boundaries are unclear or in dispute could expose them to higher risks of theft, violence and other forms of conflict such as arson.

Conclusions and implications

The above discussion of gender aspects of agriculture and forestry shows clearly that some assumptions made about the roles of women have been oversimplified. Women’s roles and potential input in agroforestry needs to be more nuanced than is typically the case. For example:

- Although decision-making about land use is typically assumed to be male-dominated. There are situations where women do make decisions, particularly in relation to the gardens near their houses and home gardens..

- Women's rights to land for productive purposes are not always simply a result of their status as wives of men with rights. Some women do use land in their own name, including for non-subsistence purposes. In addition, women who have married out of their village who return with their husbands may also have access to land. Their husbands, although outsiders, may also have access to land.

These apparently minor differences highlight the way that common generalisations about gender issues may be inaccurate. They show just how nuanced the understanding of gender has to be in planning and implementing agroforestry activities. That is a clear lesson from this research.

This paper starts from the premise that gender (especially as it refers to women) is essential for FLR and agroforestry interventions, both for human rights reasons and for practical reasons – if women do not support new land use practices they will often fail, especially as their labour is essential.

Finally, it is worth mentioning reservations about the extent to which external actors, organisations like RAIL or bilateral projects, should attempt to radically change gender relationships in PNG. This is usually not appropriate or practical. However, such reservations do not justify ignoring the gender implications of interventions. The absolute minimum standard is that women's lives should not be made worse as a result of interventions. More positively outcomes should make their lives better in ways that reflect what they see as improvements.[2]

Implications and recommendations

From the point of view of future practice in FLR and agroforestry programs there are several important implications:

- *It is essential to talk to women before anything is done in order to assess their preferences. Discussion should not be limited to discussions with men who say they want to plant trees or gardens, where they want to plant them or what species should be planted. Implication of land use changes need to be clearly understood and agreement negotiated.*

  Importantly, failing to consider women's preferences before agroforestry or reforestation acivities commence may lead to serious negative impacts on their labour.

- *Consultation should not take place just at the planning/negotiation stage. Issues emerge as activities proceed. There is thus a need for continual monitoring.*

[2] RAIL has obligations to take gender seriously under the requirements for Roundtable on Sustainable Palm Oil (RSPO) certification and Rainforest Alliance Certification.

- *It is essential to be aware of preferences commonly expressed by women, such as the need for plots to be close to the village.*

  Again, ignoring these preferences may have negative impacts on women's labour.

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Identifying Mother Trees in the Buffer Zone of Ramu Agricultural Industries Ltd. (RAIL)

Prepared by: Nestor Gregorio and Nathan Wampe

Introduction

The quality of planting materials and species diversity of trees in smallholder farms and large-scale plantations are essential factors in promoting the success of the forest and landscape restoration approach in rehabilitating deforested and degraded forests. The source of germplasm has a strong influence on seedling quality, and germplasm availability directly affects the species diversity of resulting plantations. The availability of seeds, particularly indigenous forest trees, is recognised as one of the main challenges to satisfying global restoration targets. The limited supply of seeds has adverse effects on outcomes of restoration programs due to low species and genetic species diversity of established plantations, mismatch of species to planting sites and local preferences, poor genetic trait of seedlings, and low physical quality of planting stock. Also, the lack of genetically superior germplasm would result in low financial returns from tree plantations.

Aims and objectives

This research aims to enhance the supply of high-quality germplasm of broad species base to support the smallholder tree farming and reforestation initiatives in the Ramu Valley and neighbouring municipalities. The research will be undertaken with the following objectives:

1. Identify potential phenotypically superior trees (plus trees) that will become sources of germplasm (mother trees) for tree farming initiatives and reforestation projects in Ramu Valley and adjacent localities
2. Assess the phenotypic quality of potential mother trees using the standard developed by the ACIAR Q-seedling Project (ASEM/2006/091) and determine the specific location
3. Develop a database showing the details of the mother trees
4. Monitor the phenology of identified mother trees

Methods

Staff requirement and survey instruments. The survey will require at least three persons. Two technical individuals will measure the tree parameters, and a community resident, will serve as a guide and assist the team in clearing the tracks. One of the technical persons will measure the diameter at breast height (Dbh), and the other will measure the tree height and record the data using the provided datasheet. The person measuring Dbh will also assess the stem circularity. The other person will determine the stem straightness, branching, health, branch angle and persistence. The hired community resident will assist in estimating the age of the tree. The team will need a diameter tape in measuring the Dbh and a hypsometer to determine the tree height.

***Site selection and pre-identification of potential mother trees*.** The survey will be undertaken in the buffer zones of the RAIL agricultural area. These sites are characterised by being open forests with native trees of considerable size, mainly along riverbanks. Adjacent communities accessing the buffer areas will be tapped as guides in locating the distribution of potential mother trees. Mature dominant and co-dominant trees with at least 30 cm Dbh will be identified. These trees will be assessed to determine their suitability as plus trees.

The survey involves the establishment of circular plots at 100 m intervals. The plots will be laid along a transect line following the longer side of the buffer zone. Figures 2 and 3 illustrate the method of establishing the plots, initial identification of potential mother trees, and the datasheet used to record the measured parameters and corresponding scores. Aside from describing the phenotypic characteristics, the phenology status will also be noted.

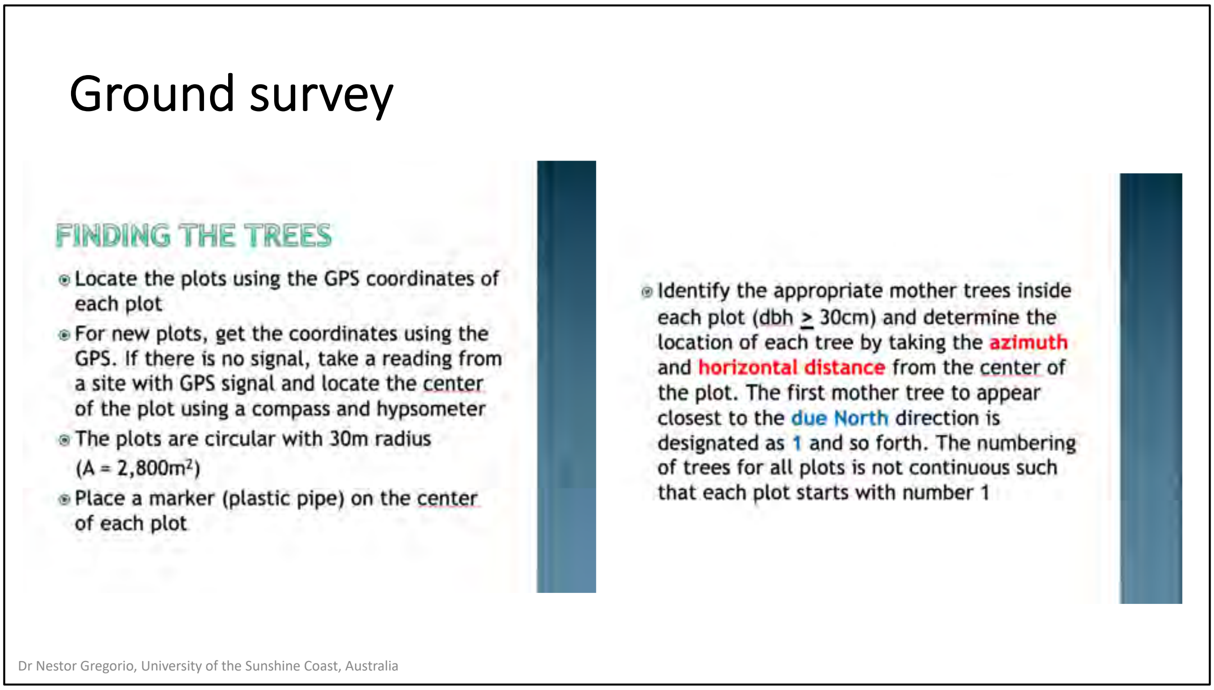
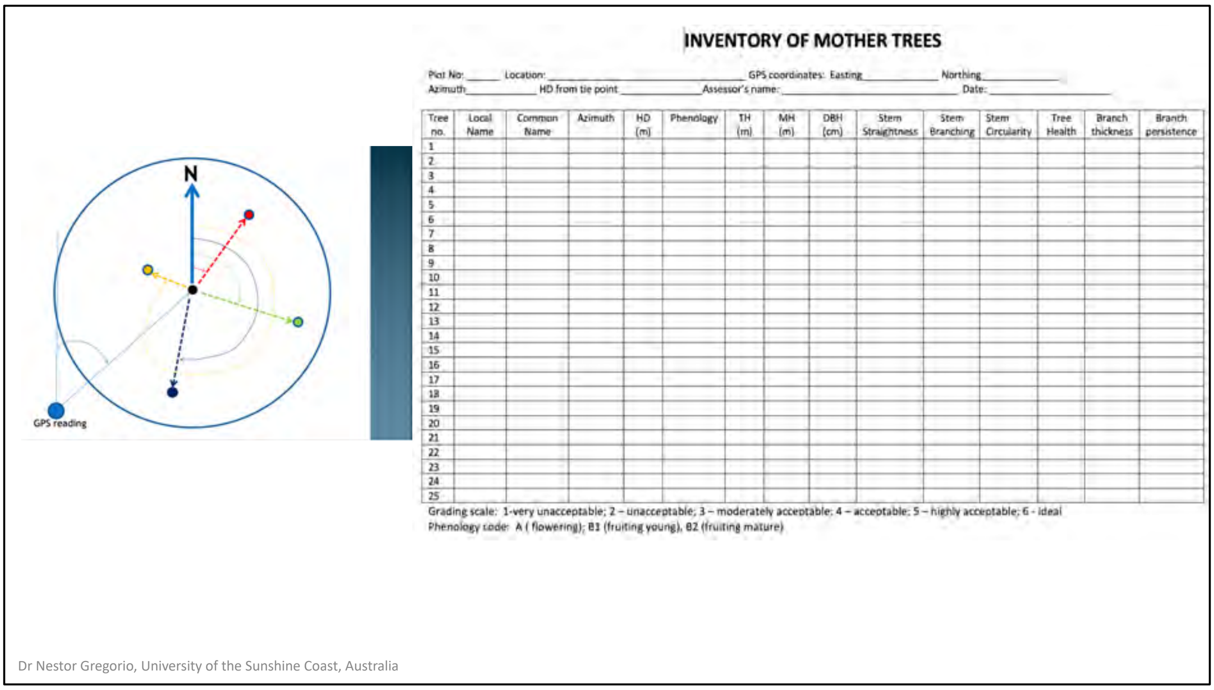


Figure 1. Steps in establishing the survey plots and initial identification of potential mother trees



INVENTORY OF MOTHER TREES

Plot No: ______ Location: ______ GPS coordinates: Easting ______ Northing ______
Azimuth ______ HD from tie point ______ Assessor's name: ______ Date: ______

Tree no.	Local Name	Common Name	Azimuth	HD (m)	Phenology	TH (m)	MH (m)	DBH (cm)	Stem Straightness	Stem Branching	Stem Circularity	Tree Health	Branch thickness	Branch persistence
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
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25														

Grading scale: 1-very unacceptable; 2 – unacceptable; 3 – moderately acceptable; 4 – acceptable; 5 – highly acceptable; 6 - ideal
Phenology code: A (flowering); B1 (fruiting young), B2 (fruiting mature)

Figure 2. Illustration of a survey plot showing the distribution of mother trees and the datasheet.

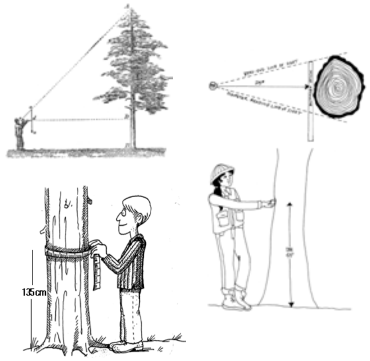
Data collection. The potential mother trees will be assessed following the method developed by the ACIAR/ASEM/2006/091 Enhancing Tree Seedling Supply via Economic and Policy Changes in the Philippine Nursery Sector. This method which combines tree measurements and expert judgements in assessing mother trees has been incorporated in the Philippine policy on Forest Nursery Accreditation. The phenotypic characteristics of the mother trees will be examined using the criteria:

stem growth, stem form, health and branching characteristics. Stem growth will be assessed by measuring the total height and Dbh. Stem form will be examined by gauging stem straightness, forking and circularity. Branching characteristics will be determined by examining the branching angle, thickness, and persistence. Figure 1 presents the criteria and parameters that will be measured to assess the phenotypic quality of potential mother trees. Each tree will be graded using a score of 1 to 6, 1 being very unacceptable and 6 as ideal (Figure 3).

Assessing the phenotypic quality of mother trees

- The set of criteria

Criterion	Parameter
Stem growth	Total height (m)
	Diameter at breast height (cm)
Stem form	Stem straightness
	Forking/stem branching
	Circularity of the stem
Health	Tree health
Branching characteristics	Branch angle
	Branch thickness and persistence



Dr Nestor Gregorio, University of the Sunshine Coast, Australia

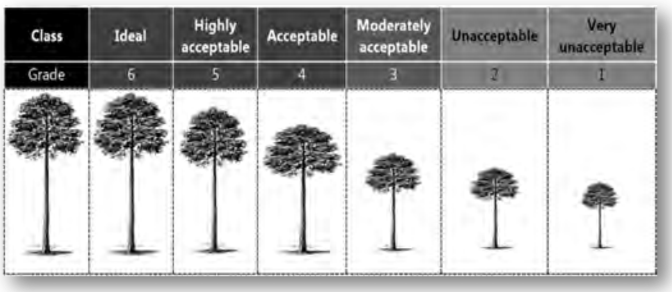
- Grading scale

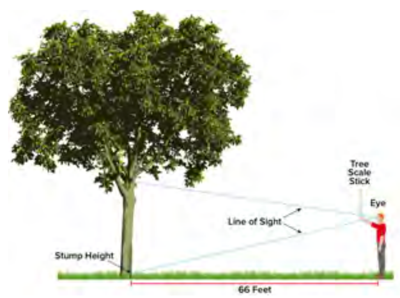
Score	
6	Ideal
5	Highly acceptable
4	Acceptable
3	Potentially acceptable
2	Unacceptable
1	Very unacceptable

Figure 3. The set of criteria and corresponding parameters to examine the phenotypic quality of potential mother trees and the scoring scale.

The tree parameters will be measured or described in the following illustrations:

- **Tree height**
  - Height of the tree in relation to its age
  - Measured from the base up to the tip of the crown using hypsometers. An expert's estimate is acceptable if hypsometers are not available.





Score	Description
6	Attained normal height given its age
5	Attained 90% of normal height
4	Attained 75% of normal height
3	Attained 50% of normal height
2	Attained 40% of normal height
1	Attained 20% or less of normal height

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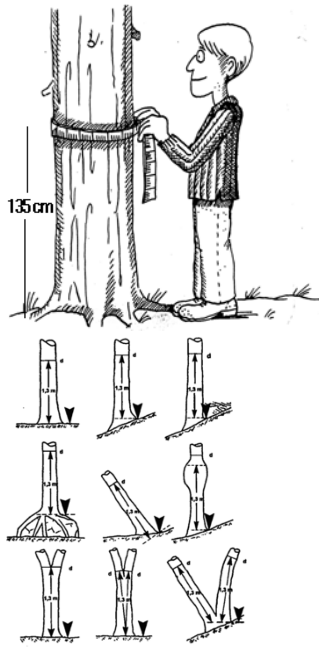
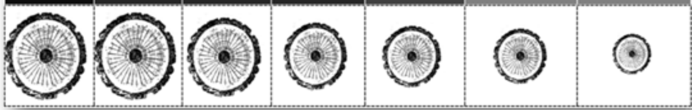
Figure 4. Measuring and assessing tree height

Diameter at breast height (Dbh)

- The size of the stem in relation to its age
- Relates to timber production capacity and sturdiness of the tree
- Measured at 1.3 m from the base using a diamater tape



Class	Ideal	Highly acceptable	Acceptable	Moderately acceptable	Unacceptable	Very unacceptable
Grade	6	5	4	3	2	1



Score	Description
6	Attained normal size given its age
5	Attained 90% of its Dbh given its age
4	Attained 75% of its Dbh given its age
3	Attained 50% of its Dbh given its age
2	Attained 40% of its Dbh given its age
1	Attained 20% or less of its Dbh given its age

Figure 5. Measuring and assessing tree diameter

Stem straightness

- Describes the position of the stem in relation to the vertical axis
- Directly related to wood quality

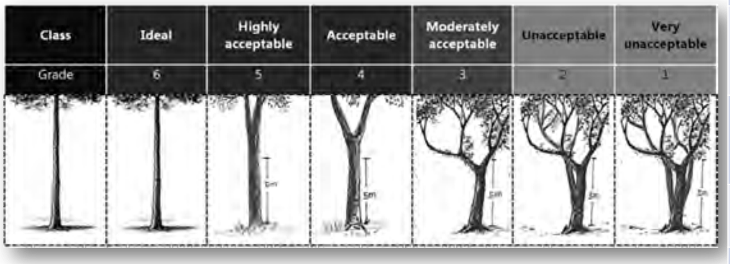
Class	Ideal	Highly acceptable	Acceptable	Moderately acceptable	Unacceptable	Very unacceptable
Grade	6	5	4	3	2	1

Score	Description
6	Straight stem
5	With a narrow bend, less than 10° from the vertical axis, occurring at 1 to 2 meters from the ground
4	A single bend of about 10° occurs on the middle part of the stem length
3	A pronounced bend of about 20° from the vertical axis is formed on the middle part of the stem length
2	Two bends about 20° within the merchantable length of the stem
1	Two bends greater the 20° within the merchantable length of the stem

Figure 6. Assessing stem straightness

▪ **Forking/stem branching**

- The presence of multiple stems instead of the normal single stem
- Forking reduces wood quality, quantity and market value
- Degree of forking is rated according to the number of forked stems and stem position where forking developed stem where the fork is formed.



Score	Description
6	Straight single stem
5	Two stem leaders developed above 5 meters from the ground, one stem is considerably smaller than the main stem
4	Two stem leaders developed above 5 meters from the ground, the stems are of the same size
3	Two stem leaders developed within 5 meters from the ground
2	Three stem leaders developed within 5 meters from the ground
1	More than three stem leaders developed within 5 meters from the ground

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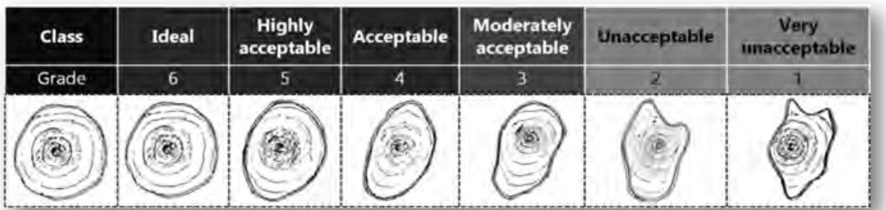
Figure 7. Assessing stem branching/forking

▪ **Stem circularity**

- Stem circularity affects wood quality and lumber recovery
- Stem circularity was determined using the overall appearance of the stem from the breast height and at 5 meters interval along the length of the stem.



Score	Description
6	Circular stem
5	Slightly oblong but circularity is still prominent
4	Slightly oblong-shaped, circularity is less prominent but no protruding corners
3	Oblong-shaped with one protruding corner
2	Oblong-shaped with two protruding corners
1	Star-shaped; showing more than two protruding corners

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Figure 8. Examining and scoring stem circularity

Tree health

- The absence of symptoms and signs of pests and diseases
- The health of the mother tree is assessed through ocular observation of the colour of the crown and degree of damage caused by pests and diseases on leaves and stem
- A stem decay extending over 25% of the diameter and height culls the tree

Class	Ideal	Highly acceptable	Acceptable	Moderately acceptable	Unacceptable	Very unacceptable
Grade	6	5	4	3	2	1
Crown not damaged	Crown not damaged	Crown is 10% damaged	Crown is 25% damaged	Crown is 50% damaged	Crown is 75% damaged	Crown is 100% damaged

Score	Description
6	The crown is not chlorotic and no observable damage by insects and pathogens
5	10% of the crown is chlorotic or damaged by insects and pathogens
4	25% of the crown is chlorotic or damaged by insects and pathogens
3	50% of the crown is chlorotic or damaged by insects and pathogens
2	75% of the crown is chlorotic or damaged by insects and pathogens
1	Over 75% of the crown is chlorotic or damaged by insects and pathogens

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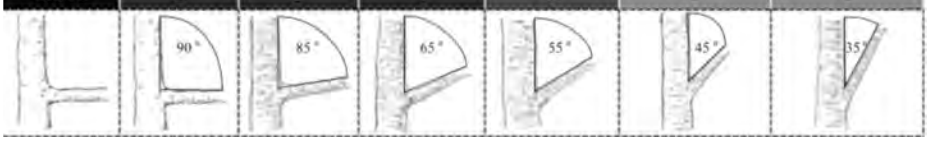
Figure 9. Assessing tree health

Branch angle

- Angle that the branch forms with the vertical axis of the tree stem
- Relates to the probability of self pruning
- Branches affect wood quality

Class	Ideal	Highly acceptable	Acceptable	Moderately acceptable	Unacceptable	Very unacceptable
Grade	6	5	4	3	2	1



Score	Description
6	Majority of mature branches are 90° from the stem axis
5	Majority of mature branches are 75° to 90° from the stem axis
4	Majority of mature branches are 60° to 75° from the stem axis
3	Majority of mature branches are 50° to 60° from the stem axis
2	Majority of mature branches are 45° to 50° from the stem axis
1	Majority of mature branches are less than 45° from the stem axis

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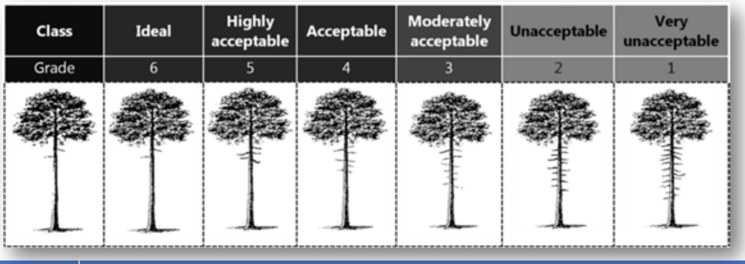
Figure 10. Scoring branch angle

- **Branch thickness and persistence**
  - Pertains to the attachment of dead branches on the stem
  - Consider branches with a diameter of at least 5 cm



Score	Description
6	When less than 3 dry branches with a diameter of at least 5 cm remain attached on the stem
5	When 3-5 dry branches with a diameter of at least 5 cm remain attached on the stem
4	When 6-8 dry branches with a diameter of at least 5 cm remain attached on the stem
3	When 9-12 dry branches with a diameter of at least 5 cm remain attached on the stem
2	When 12-15 dry branches with a diameter of at least 5 cm remain attached on the stem
1	When more than 15 dry branches with a diameter of at least 5 cm remain attached on the stem

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Figure 11. Assessing branch thickness and persistence

Data organisation. Records on the datasheet will be collated and encoded in Microsoft Excel. There is a wide array of database software that can be used depending on the preference of the project staff. Figure 12 is an example of survey data organised using Microsoft Excel.

Plot no.	Location	Easting	Northing	Azimuth	HD from tiepoint	Tree no.	Local name	Common name	Scientific name	Azimuth	HD from center (m)	Total height	MH (m)	DBH (cm)	Straightness	Branching	Circularity	Health	Branch thickness	Branch persist	Mean grade
1	Pandong Bato	0506050	0714423	65	21 m	1	Bagtikan	Bagtikan	Parashorea malaanonan	0	0	16.24	9.88	31	5	4	5	5	5	4.5	4.75
						2	Ulaian	Ulaian	Lithocarpus llanosii	25	7.84	28.25	17	100	4	3.5	4.5	3.5	4	3.5	3.75
						3	Nilo	Nilo		30	1.12	24.00	7.89	44	4	4	3.5	5	4	4	4
						4	Nato	Nato	Palaquium luzoniense	135	12.16	25.10	16.72	53	4.5	4	4.5	4.5	3.5	4	4.25
						5	Abuing	Abuing		150	13.73	28.40	19.44	66	6	5.5	5.5	5.5	5.5	6	6
						6	Ulaian	Ulaian	Lithocarpus llanosii	261	24.37	27.94	12	53	5.5	5	5	6	4	5	5.25
2	Pandong Bato	0506152	0714333	135	7.34	1	Abuing	Abuing		0	0	19.31	16.91	39	5.5	5	5	3	4.5	5	5.25
						2	Dungaw-Pula	Dungaw-Pula	Astronia rolfei	15	9.60	26.70	10.42	43	6	5.5	5	4.5	5.5	5.5	5.75
						3	Ulaian	Ulaian	Lithocarpus llanosii	20	14	16.40	7.67	33	5	4	4	5.5	4	5	5
						4	Tuai	Tuai	Bischofia javanica	87	10.84	19.40	10.99	40	4.5	4	5	5.5	5	5.5	5
						5	Ulaian	Ulaian	Lithocarpus llanosii	122	12.82	23.67	16	30	5	5	5.5	6	4.5	5	5
						6	Malakawayan	Malakawayan	Podocarpus rumphii	131	20.85	25.50	18.65	33.5	6	6	5.5	5.5	5.5	5.5	5.75
						7	Abuing	Abuing		145	28.66	28.35	17.55	55	6	5	5	5.5	5	5.5	5.75
						8	Nilo	Nilo		150	19.58	17.25	12.53	43	4	4.5	4.5	5	5	5.5	4.75
						9	Nilo	Nilo		154	15.82	23.28	10.33	41	4	4.5	5	5.5	4.5	4.5	4.25
						10	Sagimsim	Sagimsim	Syzygium brevistylum	165	14.16	22.11	13.73	44.5	4.5	5	5	6	5	5	4.75
						11	Tafros	Tafros		185	13.15	21.10	13.08	51	4.5	5	4.5	5.5	4.5	5	4.75
						12	Ulaian	Ulaian	Lithocarpus llanosii	189	5.17	21.24	9.26	40	4.5	4	4.5	4.5	4	4.5	4.5
						13	Ulaian	Ulaian	Lithocarpus llanosii	320	20.25	25.40	8.40	37	5.5	5	5.5	5.5	4.5	5	5.25
						14	Ulaian	Ulaian	Lithocarpus llanosii	330	24.10	27.30	13.5	48	5.5	4.5	5.5	5.5	4.5	5	5.25
						15	Batino	Batino	Alstonia macrophylla	145	16.52	19.37	14.30	31.5	4	4	3.5	5	4.5	5	4.5
3	Pandong Bato	0605226	0714342			1	Kalantas	Kalantas	Toona calantas	0	0	17.95	8.06	38	5	4	5.5	6	5	5.5	5.25
						2	Sagimsim	Sagimsim	Syzygium brevistylum	16	17.18	25.60	13.07	34	5	5	4.5	5	5	4.5	4.75
						3	Lang	Lang		19	22.94	28.00	11.9	32	5	5	3.5	6	5.5	5	5
						4	Bunog	Bunog	Garcinia benthami	34	22.49	30.14	14.60	48	5.5	5.5	6	6	5.5	5.5	5.5
						5	Tafros	Tafros		65	22.41	28.90	17.13	30	6	5	5	5.5	5	5.5	5.75
						6	Sagimsim	Sagimsim	Syzygium brevistylum	114	23.1	26.40	8.71	51	5	4.5	5	5	4.5	5	5
						7	Abuing	Abuing		144	21.63	30.10	19.92	41	5	5	5	5.5	5.5	5.5	5.25
						8	Dungaw-Pula	Dungaw-Pula	Astronia rolfei	175	10.76	25.10	8.17	49.5	5	4.5	5	5	5	5	5
						9	Abuing	Abuing		214	10.56	16.92	6.38	34.5	4	4.5	5	5.5	4	5	4.5
						10	Lang-kusing	Lang-kusing		271	18.28	16.30	10.64	33.5	5.5	5	5.5	6	5.5	5.5	5.5
						11	Igem	Igem	Dacrycarpus imbricatus	293	14.37	27.80	10.3	38	5.5	5.5	5.5	5	5	5	5.25
						12	Tangisang layugar	Tangisang layugan	Ficus latsoni	297	24.31	32.50	14.60	40.5	5.5	4.5	5	5.5	5	5.5	5.5
						13	Balobo	Balobo	Diplodiscus paniculatus	345	19.15	17.80	14.46	36	4.5	4.5	5	5	5.5	5.5	5
4	Pandong Bato	0506295	0714346	95	26.98	1	Abuing	Abuing		0	0	24.70	14.92	51	5.5	5.5	4.5	4.5	4	5	5.25
						2	Ulaian	Ulaian	Lithocarpus llanosii	26	22.75	22.50	14.56	37	4.5	5	4.5	5	4.5	5	4.75
						3	Adlaem	Adlaem		24	25.3	19.63	12.63	31.5	5.5	5.5	5	5	5.5	5.5	5.5
						4	Katmon	Katmon	Dillenia philippinensis	29	21.42	18.70	10.60	34	4.5	4.5	4	5	4.5	5.5	5
						5	Ulaian	Ulaian	Lithocarpus llanosii	35	10.40	21.40	13.20	34.5	4	4	4	5	4.5	5	4
						6	Ulaian	Ulaian	Lithocarpus llanosii	37	28.47	30.03	17.82	66	6	5.5	5.5	6	4.5	5.5	5.75
						7	Abuing	Abuing		43	13.96	28.40	19.10	56	5	4.5	4	4.5	4	5	5
						8	Ulaian	Ulaian	Lithocarpus llanosii	46	13.84	21.80	14.40	32	5.5	5.5	5	4.5	3.5	3	4.25
						9	Kalingag	Kalingag	Cinnamomum mercadoi	70	10.59	24.60	11.13	39	4.5	4	5	4.5	4.5	4	4.25
						10	Pagpago	Pagpago	Platea excelsa	85	17.52	18.60	11.40	38	4.5	4	5	5	4	5	4.75
						11	Hamindang	Hamindang	Macaranga bicolor	132	12.41	19.80	15.73	32.5	5	6	5	6	6	6	5.5
						12	Nilo	Nilo		139	17.35	22.50	14.64	34	5	5.5	5.5	6	5.5	6	5.5
						13	Ulaian	Ulaian	Lithocarpus llanosii	146	26.28	30.10	10.06	45	5	4.5	5.5	5	4	5	5
						14	Kalingag	Kalingag	Cinnamomum mercadoi	154	22.23	28.90	10.04	72	4	4	4.5	5	4	4	4

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Figure 12. A mother tree inventory data organised using Microsoft Excel

Mother tree monitoring and conservation strategy

Identifying mother trees is the first step towards establishing an improved supply chain of high-quality germplasm. Monitoring the mother trees and treatments to enhance the production of seeds and wildlings is an essential component of the process. It is imperative to understand the phenology of identified trees as this will guide the seedling production planning, including the scheduling of germplasm collection. The conservation of mother trees is also critical to sustaining the supply of high-quality germplasm.

Regular monitoring of mother trees is necessary. Phenological developments will be recorded. Placement of tags showing the common, family, and scientific names could be helpful in the monitoring and conservation process. Further, the engagement of local communities might help conserve the trees and monitor the fruiting and flowering regimes.

Monitoring Program to Assess Family-focused Community Forestry Initiatives

Final Report prepared for activity 2.5 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder, Grahame Applegate, Claude Saliau, Nathan Wampe, and Bob Fisher
July 2022

1 Introduction:

This report responds to project activity 2.5 'Design and implement a monitoring program to assess family-focused community forestry initiatives.' The methods intended for this activity were;

'In collaboration with PNGFA staff, a methodology for a long-term monitoring program will be developed to track the impact of reforestation activities on the landscape and communities. The focus will be on identifying key social, economic, and biophysical indicators that are robust, are simple enough to be measured at low cost, and which provide an accurate picture of the impacts of reforestation on watersheds. The monitoring program will be utilized across four communities and associated families involved in programs under FST/2011/057 and this project. The research will involve Forest Authority staff in the development and implementation.'

2 Reforestation drivers and indicators

During the design of this monitoring program, we drew heavily on literature review of reforestation indicators and drivers written by Le et al. (2012). This literature review developed a conceptual framework for planning and evaluating reforestation projects in the tropics. The planning portion of the conceptual framework was based on reforestation drivers; factors that cause the reforestation project to succeed. These drivers were categorized into four groups; technical/biophysical; socio-economic; institutional policy and management; and project characteristics (table 1). The evaluation portion of the framework was based on reforestation success indicators. These indicators were categorized into four groups; establishment success; forest growth success; environmental success; and socio-economic (table 2). Le et al. (2012) recognized that most reforestation assessments primarily focus on the early stages of reforestation and have a limited focus of the drivers of reforestation success. The Le et al. (2012), determined that by failing to properly consider the drivers of reforestation, it would be difficult to determine the cause for the success or failure of a reforestation project.

Hence, we incorporated the list of reforestation drivers and success indicators produced by Le et al. (2012). In collaboration with RAIL and PNGFA staff, we assessed each of these drivers and indicators. The drivers were assessed to see if they were an appropriate pre-assessment tool to be used on the context of small-scale reforestation in PNG. The indicators were assessed to determine if they were robust and simple enough to be measured at low cost, while being able to provide an accurate assessment of the impacts of reforestation. Drivers and indicators that were deemed to be appropriate for PNG during the assessment with RAIL and PNGFA employees are presented in tables 1 and 2.

Table 1: Reforestation drivers

Technical/biophysical drivers	Description
Site-species matching	Will tree species grow on the site?
Tree species selection	Were local people involved in the species selection process?
Site preparation	Removal of weeds, soil cultivation, and application of fertilizer.
Seedling production	Assessment on the availability of seedlings from nurseries.
Quality of seeds	Use of high-quality disease-free seed.
Appropriate time of planting	Seedlings planted at the beginning or middle of the wet season.
Technical capacity of implementers	Training provided if necessary, to ensure technical capability.
Post-establishment silviculture	Weeding, managing grazing animals, thinning, pruning, fertilizing.
Site quality	Assessment of ability of site to grow trees, such as site index.
Socio-economic drivers	
Livelihood planning	Does participation enhance the livelihoods of participants and not detract?
Local participation and involvement	People are involved and can see that participation is in their interest.
Socio-economic incentives	Improved environmental and social services will result from program.
Financial and economic viability	Appropriate selection of financial or economic analysis and viability is confirmed.
Social equity	Is there equity between stakeholders in costs and benefits?
Corruption	Is it present, if so, can it be mitigated?
Degree of dependency on forest products	Are stakeholder's dependent on the forest products (Stake in the game)?
Marketing prospects	Is there a monetary incentive for people to participate?
Knowledge of markets for forest products/services	Are people informed about the market values of the forest products/services?
Causes of forest loss and degradation	Assessment of what is causing the deforestation.
Institutional policy and management drivers	
Institutional arrangements	Clear land tenure, legal framework, laws/regulations, etc.
Effective governance	Rule of law, responsiveness, transparency, efficiency, accountability, etc.
Forest harvesting policies and other forest policies	Clear and consistent policies.
Tenure security	Clearly defined and mechanism for conflict resolution.
Long-term management planning	Is it present?
Long-term maintenance and protection of sites	Is it present?
Forestry support programs	Are extension services present?
Presence of community organizer	Does this role exist?
Community leadership	What is the viewed strength of community leadership?
Risk involved	Requires an assessment of risk.
Project characteristics	
Project goals/objectives	Are both conservation and economic development present?
Project location or accessibility of sites	Is reforestation site easily accessible for stakeholders?
Project size	Does project size objectives fit with abilities/interests of stakeholders?
Project funding	Expected timeline and adequacy of the funding.

Table 2: Reforestation indicators

Establishment success (3-5 years after planting)
Survival rate %
Area planted vs. target area %
Forest growth success (5 years+ after planting)
Basal area
Height
Stem form
Stand density
Environmental success (5 years+ after planting)
Vegetation structure
Canopy cover
Canopy height
Ground cover
Litter cover
Shrub cover
Snags (dead trees)
Species diversity
Tree species richness
Presence of desired species
Appropriate wildlife species present
Special life forms present
Weed abundance
Ecosystem functions
Stable soil surface
Soil erosion
Soil fertility
Landslide frequency
Adequate quantity of surface and ground water
Water quality
Soil organic matter
Biomass productivity
Carbon sequestration
Socio-economic (5 years+ after planting)
Increased income
Local employment opportunities
Other livelihood opportunities
Availability of food and fiber supplies
Stability of market prices of locally produced commodities
Local empowerment and capacity building

3 Reforestation sites and scoring of drivers

Reforestation activities were planned to occur at three sites in the Ramu Vally, and in the PNG highlands. The three sites in the Ramu Valley are Atzunas, Bopirumpun, and Marawasa. At the stages of the project, there was a dispute between two of the landowners at Marawasa, which resulted in a cessation of reforestation activities there.

4 Description of reforestation activities:

After assessing the drivers for our selected sites, it was determined that it would be necessary to conduct additional pre-reforestation activities to address potential deficiencies in the technical/biophysical drivers and socio-economic drivers. These activities were research interviews/meetings, trainings in nursery production, and assisting families in developing their own small-scale nurseries. These interviews/meetings involved meetings with community leaders to discuss the project, interviewing individuals in communities to identify their preferences for implementing family-based agroforestry, meetings to discuss how the people would participate in the research, and meetings to discuss formal agreements for participation. These interviews/meetings were held at every community where the research was conducted.

Nursery training was provided by ACIAR project partners for individuals in the selected communities. The nursery training activities were how to; source high quality germplasm/seed, assemble a small-scale nursery, properly prepare soil, germinate the seeds, transfer seedlings to polybags, transfer seedlings to hardening beds, and plant the seedlings. Each community received an initial training and some communities received follow-up trainings. Nursery production was the third stage of the reforestation activities. This involved families and individuals in the communities implementing the training they received to establish their own nurseries and plant the seedlings they generated.

We made multiple measurements of the level of reforestation activity conducted at each of selected sites.

4.1 Measurements for meetings/interviews

The first measurement recorded was geographical; the name of the community and the name of the hamlet if available. The second measurement recorded was the date of the visit. From the first two measurements, it was possible to identify the total number of visits/engagements by site. This also allowed us to measure the number of people that were met with/interviewed by sex. This allowed for identifying the total number of people that were engaged with by site and sex.

4.2 Measurements for nursery training

The measurements for the nursery training were identical to those used for the meetings/interviews. In some cases, it was not possible for the trainers to count the number of training attendees by sex and only a total attendance was recorded.

4.3 Measurements for nursery production and seedlings planted

The first measurement that was recorded was geographical; the name of the community. The second measurement was the name of the family/individual that had established the nursery. These measurements allowed us to identify the number of families and participants by community. Initially we were measuring the change in the number of seedlings in polybags and in hardening beds for each participating smallholder nursery. However, it soon became too difficult for project personnel to keep up with this metric, so the measurements eventually only focused on the number of seedlings planted.

The measurements regarding plantings were the number of seedlings planted, how people planted their trees, and the spacing between trees. This allowed us to determine if people were planting trees along a property boundary in a straight line, in a plantation/grid format, or by randomly placing individual trees. By identifying the number of trees, the planting pattern, and the spacing, we were able estimate the area of trees planted. These ‘seedlings planted measurements’ to measure the ‘establishment success indicators’ written up by Le et al. (2012), which will likely occur 3-5 years after the seedlings were planted.

4 Data recording methods for reforestation activities:

Data recording methods utilized a four-step process. The first step was for the project partners conducting the pre-reforestation field activities to take detailed hand-written notes during their visits. The second step was for these same partners to utilize the hand-written notes to write up field reports that described those activities undertaken during the visit. These field reports were to include all the measurements discussed in section three. To protect the identities of the community participants, each participant was given a code. Each code has four digits. The first digit is the first letter of the name of the community. The second digit was an ‘M’ if the participant was a male, or ‘F’ if the participant is a female. The last two digits were simply an assigned number; 01, 02, 03, etc. These field reports were to be shared with the entire ACIAR project team.

The third step of the data recording process was the input of the measurements discussed above into a Microsoft Excel monitoring document. This excel document was designed by the author of this report. Each sheet in the document is specific to each community and includes measurements and the derived key indicators for each of the three reforestation activities. Within the monitoring document, there is a total summary sheet that utilizes referencing formulas linked to each community sheet. This allows for total reforestation summary tables to be produced (tables 3 and 4). The author of this report is the individual responsible for updating the excel monitoring document. The fourth step in the data recording process is for the Microsoft Excel Monitoring document and this report to be shared with all the project partners. This is to aid in identifying any errors that occurred during the recording process and to ensure that all the reforestation data is transparent and freely available.

5 Results

This report contains the results of reforestation activities up to February 2021. At this time, a total of 3,641 recorded trees have been planted. A total of 239 people participated in the nursery trainings. At least seven of the nursery training participants were women. During the initial engagement meetings/interviews, a total of 111 people participated, with at least 32 of them being women.

Unfortunately, the Covid-19 pandemic had several negative impacts to this project activity. Communication challenges and the inability of Australian project partners to travel to PNG was the primary difficulty experienced. The PNG project partners also experienced a limited ability to travel to the project sites. As such, the ability to continue to collect the reforestation data was degraded. Reforestation data was collected from the period of August 2020 to February 2021, but the level of detail that had been previously collected ceased. Additional data on the reforestation activities being conducted in the highlands was not able to be compiled and shared with the project team.

It is estimated that approximately 4.76 ha were reforested (recorded trees planted). A wide variety of tree spacing measurements were used. The average number of trees per hectare was 765. However, these were planted in areas that were less than one hectare in area. Approximately 83% of the plantings were done as area plots, and the remaining 14% were planted to mark out garden or property boundaries. The average number of trees planted per farmer was 77. The observed trends in tree plantings by community, hamlet, gender, and species, and planting type/system is presented in figures 1, 2, 3, and 4. These figures only present data up to the second quarter of 2020, as the level of detail in the data collected declined during the pandemic.

Bob

Table 3: Reforestation engagements and trainings

Date	Community	Hamlet	Male attend.	Female attend.	Total attend.	Training type	Main species	Other species
Oct-18	Atzunas	Unknown	Unknown	Unknown	90	Nursery	*Eucalyptus pellita*	Unknown
Jan-19	Atzunas	Unknown	6	0	6	Nursery follow-up	*Eucalyptus pellita*	Unknown
Jan-19	Marawasa	Unknown	Unknown	Unknown	30	Nursery	*Eucalyptus pellita, Canarium indicum*	*Unknown*
Jul-19	Bopirumpun	Gagki	23	7	30	Nursery	*Eucalyptus pellita*	*Intsia bijuga, Canarium idicum,* Klinki pine, Tulip tree
Oct-19	Bopirumpun	Gagki	Unknown	Unknown	16	Nursery	*Eucalyptus pellita*	*Intsia bijuga, Canarium idicum*
Oct-19	Bopirumpun	Sunki	Unknown	Unknown	16	Nursery	*Eucalyptus pellita*	*Intsia bijuga, Canarium idicum*
Oct-19	Bopirumpun	Puara	Unknown	Unknown	16	Nursery	*Eucalyptus pellita*	*Intsia bijuga, Canarium idicum*
Jul-20	Bopirumpun	Unknown	Unknown	Unknown	7	Nursery	Unknown	Unknown
Aug-20	Bopirumpun	Unknown	Unknown	Unknown	7	Nursery	Unknown	Unknown
Nov-20	Musuam	Unknown	Unknown	Unknown	6	Nursery	Unknown	Unknown
Feb-21	Bopirumpun	Tapi	Unknown	Unknown	15		Unknown	Unknown
Total					239			

Note: In some cases, it was not possible to count the number of people by sex, just the total. Therefore, the number of people by sex does not always add up to the total.

Table 4: Reforestation seedlings and area planted

Date	Community	Hamlet	Species	Trees	Spacing (m)	Area (ha)	Planting type	Planting system	Terrain
Oct-19	Atzunas	Omang	*Eucalyptus pellita*	120	3x2	0.07	Plot	Woodlot	Flat
Oct-19	Bopirumpun	Gaki	*Eucalyptus pellita*	35	4x4	0.06	Plot	Food crop, Cocoa	Flat
Nov-19	Bopirumpun	Puara	*Eucalyptus pellita*	41	4x4	0.07	Plot	Food crop, Cocoa	Flat
Nov-19	Bopirumpun	Puara	*Intsia bijuga*	14	4x4	0.02	Boundary	Food crop, Cocoa	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	35	3x3	0.02	Plot	Food crop	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	68	3x2	0.04	Plot	Woodlot	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	50	4x4	0.04	Boundary	Food crop, Cocoa	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	150	3x3	0.14	Plot	Woodlot	Hilltop
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	10	3x3	0.01	Boundary	Food crop	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	10	2x2	0.01	Boundary	Food crop, Cocoa	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	50	3x3	0.05	Plot	Food crop, Cocoa	Flat
Feb-20	Atzunas	Omang	*Eucalyptus pellita*	10	3x3	0.01	Boundary	Food crop, Cocoa	Flat
Feb-20	Bopirumpun	Gaki	*Eucalyptus pellita*	43	4x4	0.07	Boundary	Food crop, Cocoa	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	43	4x4	0.07	Unknown	Unknown	Flat
Feb-20	Bopirumpun	Sunki	*Eucalyptus teriticornus*	150	3x4	0.18	Plot	Woodlot, Food crop	Flat
Feb-20	Bopirumpun	Sunki	*Eucalyptus teriticornus*	150	3x4	0.18	Boundary	Woodlot, Food crop	Flat
Feb-20	Bopirumpun	Gaki	*Eucalyptus pellita*	55	4x4	0.09	Plot	Food crop	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	400	4x4	0.64	Plot	Woodlot, Food crop, Cocoa	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	25	4x4	0.04	Plot	Woodlot	Flat
Feb-20	Bopirumpun	Puara	*Intsia bijuga*	8	4x4	0.01	Boundary	Woodlot	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	20	3x3	0.02	Unknown	Food crop, Cocoa	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	20	4x4	0.03	Plot	Woodlot	Flat
Feb-20	Bopirumpun	Puara	*Eucalyptus pellita*	20	4x4	0.03	Plot	Woodlot	Flat

Date	Community	Hamlet	Species	Trees	Spacing (m)	Area (ha)	Planting type	Planting system	Terrain
Feb-20	Bopirumpun	Sunki	*Eucalyptus pellita*	256	3x3	0.23	Plot	Food crop	Flat
Feb-20	Bopirumpun	Baru	*Eucalyptus pellita*	110	4x5	0.22	Plot	Food crop	Flat
Mar-20	Bopirumpun	Gaki	*Eucalyptus pellita*	20	4x4	0.02	Boundary	Woodlot	Flat
Mar-20	Bopirumpun	Sunki	*Eucalyptus pellita*	166	4x4	0.27	Plot	Food crop	Hilltop
Apr-20	Bopirumpun	Gaki	*Eucalyptus pellita*	20	4x4	0.02	Boundary	Woodlot	Flat
May-20	Bopirumpun	Gaki	*Eucalyptus pellita*	100	4x4	0.16	Plot	Food crop	Flat
May-20	Bopirumpun	Undi	*Eucalyptus pellita*	116	4x5	0.23	Plot	Food crop, Cocoa	Flat
Aug-20 - Feb-21	Bopirumpun	Kuang, Tapi	*Eucalyputs pellita, Eucalyptus teritcornus*	746	Unknown	Unknown	Unknown	Unknown	Unknown
Aug-20 - Feb-21	Bopirumpun	Unknown	*Eucalyptus pellita, Acacia mangium*	380	Unknown	Unknown	Home garden, Boundary	Unknown	Unknown
Aug-20 - Feb-21	Bopirumpun	Sunki	*Eucalyptus pellita*	200	Unknown	Unknown	Home garden	Unknown	Unknown
Total				**3,641**		**≈ 4.76**			

Figure 1: Observed trees planted by community and hamlet

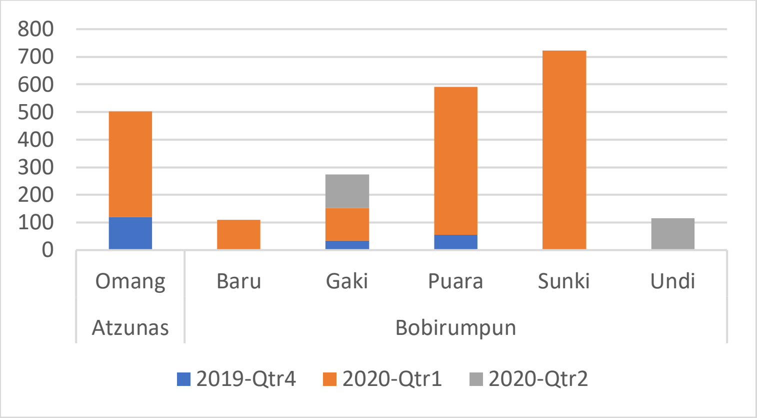


Figure 2: Observed trees planted by gender and community

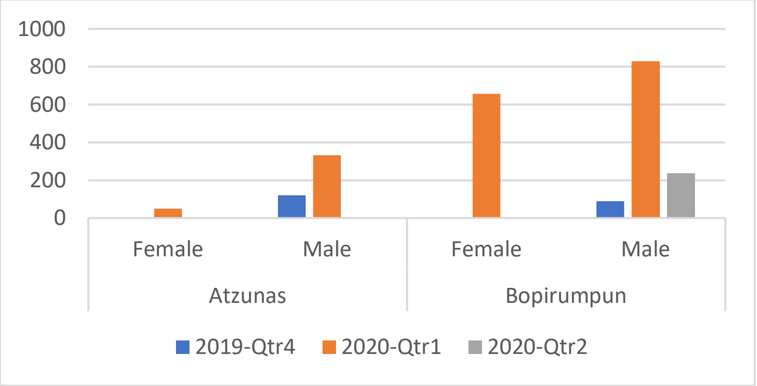


Figure 3: Observed trees planted by species, community, and hamlet

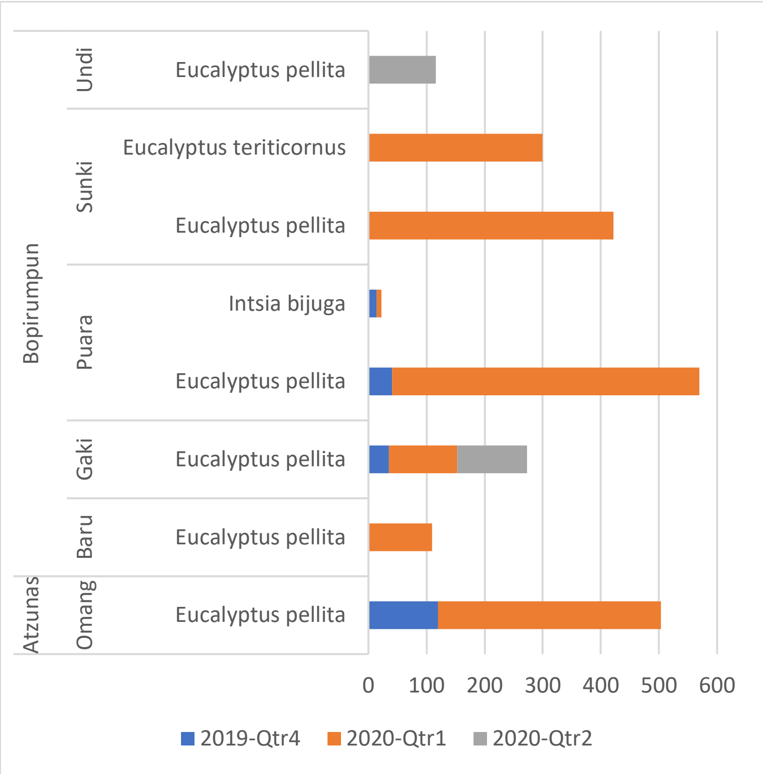
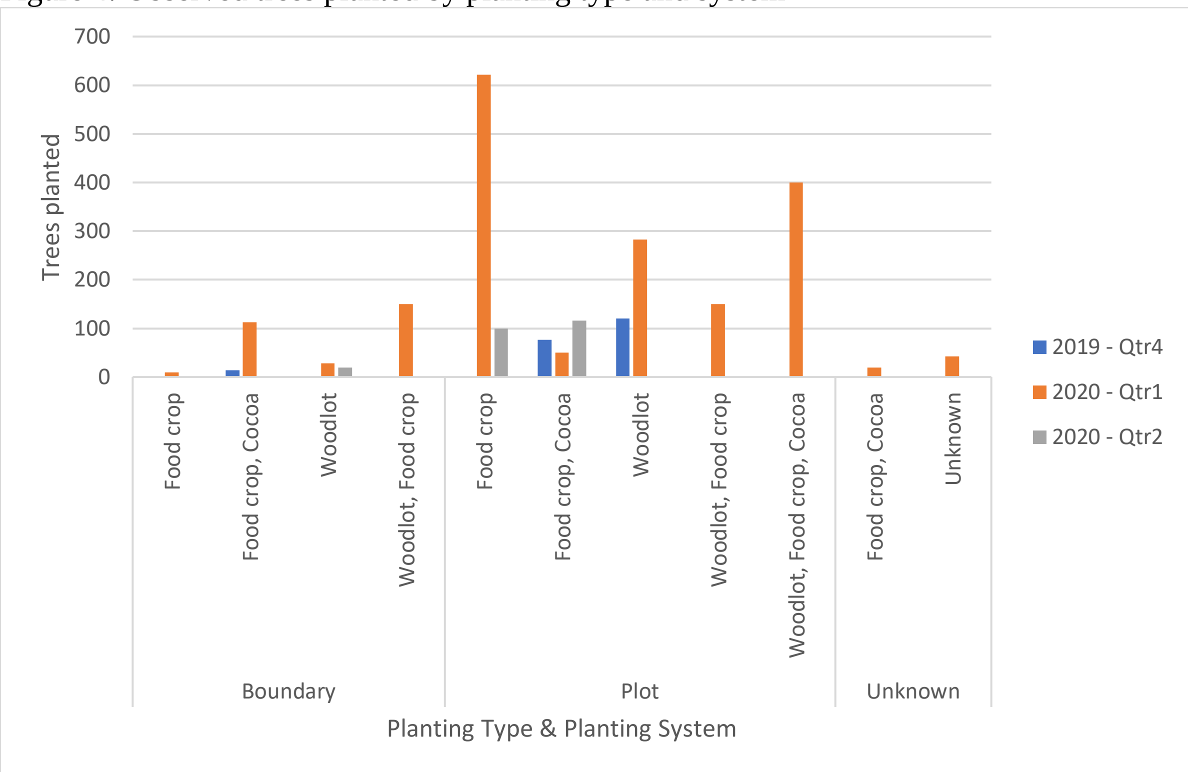


Figure 4: Observed trees planted by planting type and system



6 Conclusion:

The purpose of this report was to design and implement a monitoring program to assess family-focused community forestry initiatives and describe the methods that have been implemented to monitor the reforestation activities taking place in the project. The reforestation drivers and indicators of success are based on findings by Le et al. (2012). These drivers and indicators have been reviewed in collaboration with the PNGFA to select the ones that are appropriate for the reforestation activities in PNG.

The measurements of the reforestation success indicators will likely occur after the project has concluded. In the absence of additional funding, our measurements and monitoring plan will have to pass to another organization in PNG that can continue to assess and monitor this reforestation project.

References

Le, H.D., Smith, C., Herbohn, J., and Harrison, S. (2012). More than just trees: Assessing reforestation success in tropical developing countries. Journal of Rural Studies (28):1.

Constraints of the Timber Authority Harvest Permit and Options for Improvement

Final Report prepared for activities 3.1 and 3.2 for the mid-term review of ACIAR project FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder, Claude Saliau, and Grahame Applegate
June 2019

1 Introduction:

This report responds to project activity 3.1 'Identify key constraints associated with the current Timber Authority (TA) harvest permit process for clans to access formal timber markets' and activity 3.2 'Identify possible ways to improve the TA process for ecoforestry.' The methods intended for these activities were;

'Action research working with selected forest communities, small-scale timber producers and the Papua New Guinea Forest Authority (PNGFA) to identify key constraints to the TA harvest permit and to facilitate improved access to formal timber markets for clan-based forestry operations. The research was to involve field-based group interviews and semi-structured interviews with rural forest communities. The research was to include participant observation of meetings and activities along with detailed discussions with PNGFA. The research was to also include an understanding of the community dynamics, decision-making processes and institutional arrangements in relation to natural forest management, which was to be an input into the development of an alternative model. The findings of the initial interviews were to be discussed in collaboration with staff from the PNGFA Policy Directorate for the review and revision of the TA requirements, including the required documentation and associated costs for communities involved in ecoforestry. There was to be an assessment of what level of costs are appropriate for communities to bear and the role that entrepreneurs can play in helping communities capture the value of their forest resources through access to value-added markets.'

Background information of the TA Harvest Permit

There are five specific arrangements of the TA; TA-01 Domestic Processing; TA-02 Road line Clearance; TA-03 Agricultural and Other Land Use; TA-04 Other Forest Produce (non-timber forest products); and TA-05 Plantation Harvesting. A TA for domestic processing allows a registered 'forest industry participant' (FIP) to harvest up to and not exceeding 5,000 m^3 over the duration of one year, through selectively harvesting from the natural forest for the purpose of downstream processing (Forestry Act 1991). The Forestry Act defines a FIP, as, 'Any person engaging in, or intending to engage in, forest industry activities (otherwise than as an employee of a forest industry participant or in the capacity of a common carrier) where the timber or rattan harvested, processed, bought, sold or arranged or procured to be sold or purchased, by that person in a calendar year exceeds – (a) 500 m^3 in volume; or (b) in the case of sandalwood timber or rattan – 20,000 Kina in market value.' A complete description of the requirements for the TA process is presented in Appendix A.

The Forestry Act (1991) does not clearly define the regulations for timber harvests less than 500 m^3. The Act implies that individuals can harvest up to 500 m^3 per annum for personal use, but not for commercial purposes. The Forestry Act (1991) does not define what qualifies as commercial use versus personal use. This vagueness in the wording has resulted in different interpretations of what the intent is for harvests less than 500 m^3. The predominant view in the PNGFA is that personal use refers to harvesting timber for constructing personal homes, other personal buildings, and for fuel wood. Commercial use refers to the exchange of timber for money and/or other goods, which is predominantly viewed as a violation of the regulations.

2 Methods:

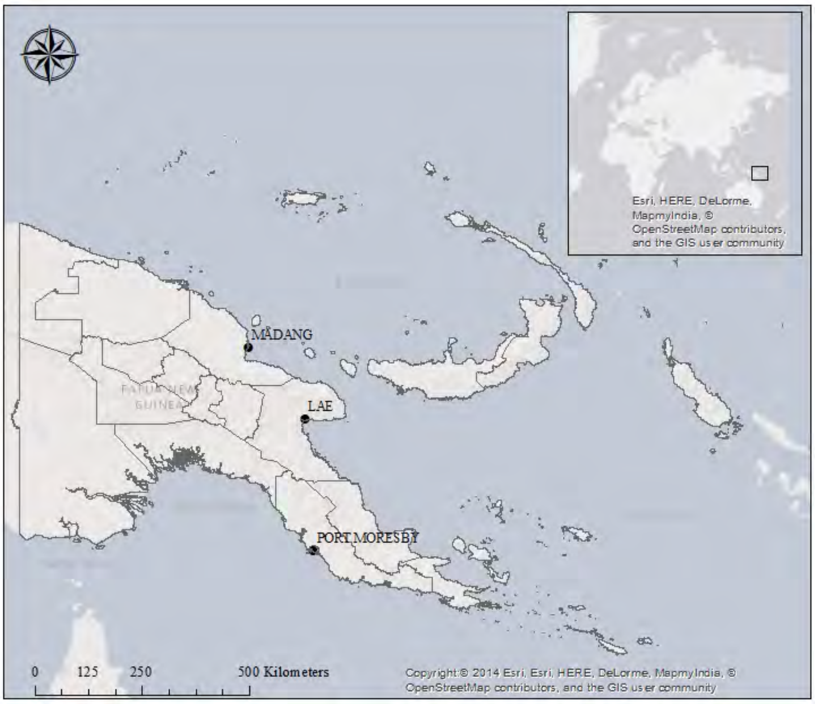
The methods used to conduct interviews with rural forest communities, small-scale timber producers, and non-participant stakeholders are described below.

Site Selection

The rural forest communities selected for interviews were in the Morobe Province on the outskirts of Lae. We visited six forest resource owner (FRO) sites. Of those six sites, four FROs owned their own portable sawmills and the other two did not. The small-scale timber producers that we selected for interviews were also near the city of Lae, as well as in the neighbouring Madang Province near the city of Madang[1]. We categorized the small-scale timber producers into two groups; those that only owned portable sawmills; and those that owned portable sawmills and additional wood machining equipment (small-scale manufacturing business).

We also conducted additional interviews with non-participant stakeholders that had expertise in forestry in PNG. In Lae, we interviewed seven professor/teachers from the Timber and Forestry Training College. In Madang, we interviewed four employees of the Foundation for People and Community Development, an ecoforestry focused non-governmental organization (NGO). In Madang, we also interviewed four provincial staff members of the PNGFA. In Port Moresby we interviewed an additional eight PNGFA staff members, a forestry professor from the University of PNG, a conservation and community development NGO representative, and two logging industry representatives. A total of 50 people were interviewed for this research.

Figure 1: Location of research sites



[1] The interviews in Madang were conducted during phase one of this project; ACIAR FST/2012/092.

Table 1: Descriptions and number of interviewees

FROs and small-scale timber producers	Participants	Interviewees
Forest Resource Owner	6	8
Sawmill owner only	6	6
Small-scale manufacturing business	7	9
Total	19	23
Non-participant stakeholders	Organizations	Interviewees
PNG Forest Authority	1	12
Foundation for People and Community Development	1	4
Timber and Forestry Training College	1	7
University of PNG	1	1
Partners with Melanesia	1	1
Sociele Generale de Surveillance (SGS)	1	1
Forest Industry Association (FIA)	1	1
Total	7	27

Interview data collection

The interviews were primarily conducted by the first author, with participation also provided by the second and third authors and a former research forester of the Tropical Forestry and People Research Centre. The initial questions asked of FROs and small-scale timber producers were; their perceptions of the TA; if they followed the TA regulations during timber harvests; and what they disliked about the TA regulations. This was followed up with additional questions related to community dynamics, decision making processes and institutional arrangements. These follow up question were; why people sold their timber; when they typically sold their timber; and where timber/wood products were sold and to whom. The interview format was similar for all interviewees. Hand-written notes were taken by the interviewers during all interviews. The length of the interviews varied between 30 minutes and one hour. At least one non-participant stakeholder was present at all the interviews with FROs and the small-scale timber producers to provide their post-interview perspective to the interviewers.

Data analysis

To address internal validity, we conducted a pattern recognition analysis of the data by arranging the rows of the database to represent the individual participants and the columns of the database to represent the questions asked to the interviewees. When we identified similar responses to interview questions we calculated the percentage of responses relative to the total. We also assessed patterns within the groups by filtering the data for; FROs, saw-miller only, and small-scale manufacturing businesses. We triangulated the interview data by collaborating it with additional evidence in the documents that we collected. Finally, we shared our findings with the non-participant stakeholder interviewees to get their perspectives.

3 Results:

We found that there are numerous constraints in the current TA process, which are acting as a hindrance to FROs desiring to access formal timber markets. We arranged these constraints into two primary categories. The first category was the structure of the TA being an inappropriate fit for most FROs and small-scale timber producers. The FROs typically chose to sell their timber to address immediate monetary needs, that did not match up with the timeframe of a TA. The small-scale timber producers also tended to operate on a harvest time-frame that did not match the TA structure. In addition, these harvests were typically much smaller than the TA allotment. The second category of constraints we identified was related to the complex bureaucratic requirements and costs of the TA regulations. These requirements and costs often exceeded the human knowledge capacity and financial capacity of the FROs and small-scale timber producers.

Reasons FROs choose to sell their timber

FROs chose to sell timber to obtain cash to be used for five main purposes; school fees; store bought goods; ceremonies; to build a home; and for Christmas celebrations. School fees were the most common response, being mentioned by 53% of the FROs/small-scale timber producers and corroborated by six of the non-participant stakeholders. This was initially misleading, because the PNG government passed legislation for the Tuition Fee Free (TFF) education policy in 2012 (DOE 2012). The purpose of the TFF policy was to abolish school fees for elementary and primary students, reduce fees for secondary students, and devolve the responsibility of fiscal management from the central government to the local schools and the district administrations. This policy also banned schools from charging additional fees to increase access to education for impoverished families. However, distribution of TFF subsidy funds from the central government to schools were often late or not able to cover all the school's expenses due to increased student enrolment (Paraide 2015 and Walton 2018). Research on educational attainment in PNG has found that 50% of households with school-aged children had difficulty in sending at least some of their children to school and only a small amount of families did not pay any school fees (Ryan et al. 2017). Interviews with non-participant stakeholders revealed that the schools adapted to the lateness or shortage of TFF subsidies by continuing to charge fees under a different name, such as 'project fees.' The PNG Education Plan 2015-2019 projected that parent-paid project fees would range from 145 to 178 Kina per student during years 2016 to 2019 (DOE 2016). An online article by the PNG Education News Website (PNGENW 2018), discussed the increase of project fees in the East New Britain Province for years 2018 to 2020. The fees were increased to 150 Kina for elementary students (Grades 1 & 2), 300 Kina for primary students (Grades 3-8), 1,000 Kina for secondary students (Grades 9-12), and 800 Kina for technical and vocational school students. The article indicated that 60% of the fees were due upon enrolment, with the remainder due by the second term. Interviews with non-participant stakeholders revealed that school enrolment occurred during January. The non-participant stakeholders also explained to us that the term 'school fees' is often used to describe all expenses related to school; the actual school fees, project fees, stationary, uniforms, and transportation to school.

The second most common reason that FROs sold their timber was to get money for the purchase of store-bought goods, which was mentioned by 42% of the FROs/small-scale producers. Store-bought goods refer to consumables that FROs cannot provide for themselves, such as clothing, packaged rice, and canned meats. The remaining reasons mentioned by the cases as reasons that FROs sold their timber were ceremonies (21%), home construction (16%), and Christmas celebrations (11%). Ceremonies were typically referred to as weddings and funerals. One of the FROs we interviewed was in the process of building a new home. We were told that the non-lumber home construction materials that he needed to purchase were nails, plywood, metal siding, roofing materials, doors, windows, and window screens. The additional cost to purchase these materials and hire a carpenter was approximately 7,500 Kina. Money needed for Christmas celebrations was for the purchase of food to be shared with family members.

Why the TA structure is an inappropriate fit for small-scale timber producers

We found that the timber harvest volumes of all the portable sawmill owners were substantially smaller than the TA harvest allotment of 5,000 m^3. The majority of saw millers produced less than 100 m^3 of lumber annually. Assuming a lumber recovery rate of 45%, this equates to less than 225 m^3 of logs harvested. Only two of the saw millers that were not also manufacturing businesses produced an annual volume that was greater than 300 m^3 of lumber. With a recovery rate of 45%, this equates to less than 670 m^3 of logs harvested. One of the FROs we interviewed told us that using the TA harvest permit was problematic because there is an expectation by the FROs that 5,000 m^3 will be harvested. If production targets were not achieved, which was usually the case, it resulted in disappointment and often conflict.

Two of the manufacturing businesses owned multiple portable sawmills and were capable of milling much larger volumes of lumber. However, they only conducted harvests at sites owned by individual families to avoid payment distribution conflicts that were common on sites owned by multiple families or clans. We were told that the individual family harvest sites were typically between 20 to 50 hectares and not able to supply 5,000 m^3 of logs. We estimated that if a sawmill owner operating one mill could secure an agreement with a family that had forest land capable of supplying 5,000 m^3, it would take 1,250 days to complete the harvest and milling, assuming a daily log input of 4 m^3. This is well beyond the one-year timeline of the current requirements of the TA and would require more than six portable sawmills to reach the 5,000 m^3 production target, assuming 200 operating days per year and 4 m^3 of log input per day.

Bureaucratic nature and costs of the TA process

The process requirements for receiving a TA begin with an individual becoming a registered FIP. This requires the creation of a legal business entity, a completed registration form delivered to the Managing Director of the PNGFA in Port Moresby, and an application fee of 100 Kina by way of bank cheque (Forestry Act 1991). The second requirement is for the registered FIP to begin the TA application process. This requires a map and description of the proposed harvest area, the harvest commencement date, the expected harvest volume, a 275 Kina application fee, and the submission of a 20,000 Kina performance bond that is only released after the submission of a harvest completion report and verification that all terms and conditions of the TA were met (NFS 1991a). In addition, the TA application requires a verification of ownership and consent of landowners (Form 165) be completed by every incorporated land group[2], or individual having ownership rights over timber or forest products within the proposed harvest area (NFS 1991b). All the Form 165s must be signed in the village where the landowners live and be witnessed by a Village Court Magistrate or Land Mediator. The TA application also requires a Sales and Purchase Agreement (Form 166) be completed and signed by all parties involved in the agreement. (NFS 1991c). After all the required documents and fees have been submitted to the PNGFA Managing Director, the application is processed. For a TA application to be granted, it will have to be approved by the PNGFA Managing Director, the Forest Management Committee of the appropriate provincial forest, the Chairman of said Forest Management Committee, and the Forest Board[3]. Non-participant stakeholders revealed that the time required to process an application is typically several months.

[2] We were told that individuals wanting to be part of an Incorporated Land Group must obtain a valid birth certificate at a cost of 15 Kina, which is an additional financial hindrance for many FROs.
[3] The Forest Board oversees the PNGFA and is chaired by the Forest Minister.

The Forestry Act (1991) requires that FIPs operating with a TA make royalty payments to the FROs for all timber harvested. The requirements for Forms 165 and 166 that were discussed above, and the payment of royalties to FROs must occur even if the FROs are the registered FIPs conducting the harvest on their own land. The royalty payment amounts are minimum fixed rates and vary between 10 and 35 Kina (PGK) per m^3, depending on the tree species. This is equivalent to $2.97 and $10.40 in 2018 USD using a conversion rate of 0.2970 Kina per 1.0 U.S. Dollar (NFS 2008, BPNG 2018) (Table 2). The timber species in PNG are categorized into four groups, with Group 1 representing the most sought-after species. The fixed-rate royalties have been in effect since 1 March 2008. Prior to this date, the minimum fixed-rate was 10 Kina (PGK) per m^3 for all species, which was set by the PNG Forestry Act (1991).

Table 2: PNG timber royalty rates per m^3 (2018 PGK and USD)

Group/Species	PGK	USD
Group 1		
Intsia bijuga	35.00	$10.40
Palaquium spp.	20.00	$5.94
Dracontomelon dao	20.00	$5.94
Remaining Group 1 species	15.00	$4.46
Groups 2, 3 and 4 species	10.00	$2.97

We found that all 19 of the FROs/small-scale timber producers had been involved in commercial timber harvests without a TA harvest permit. Only two of the participants had ever acquired a TA and 50% of the participants that were not manufacturing businesses were not even aware of the TA regulations. Those that were aware of the TA regulations indicated that FROs were not concerned about government regulations because they owned the land and would use it in any way they chose. Another common reason given for not applying for a TA was the requirement of the 20,000 Kina performance bond. None of the sawmill operators that were aware of the TA regulations had the financial means to pay the bond. This challenge has been identified by others and included as part of a policy brief to the government (Bun 2012).

Implication of the current TA system

We identified numerous constraints in the current TA system that are hindering FROs from accessing formal timber markets. The implication is that the FROs/small-scale timber producer participants have mitigated these constraints by creating and operating in an informal timber market that functions outside the view and regulations of the PNG government. Research has been conducted on this informal timber market simultaneously with research for this report, which share many of the same findings. This research has resulted in completion of paper by Scudder et al. (2019a), titled 'Addressing small-scale forestry informal markets through forest policy: A case study in Papua New Guinea.'

A related issue to the constraints of the TA, is the current timber royalty system. Research by Scudder et al. (2019b), found that the use of the fixed-rate royalty system has resulted in the real value of timber royalties for different species declining by between 32% and 66% since 1991. This research also found that FROs are currently receiving an average of 5% of the market value of logs harvested in the formal timber market from timber royalties, while the PNG government is collecting an average 32.5% of the market value through log export duties.

The effect of the relatively low share in market value being collected by FROs and the continuously declining real value of the royalties is that FROs have an increased incentive to participate in the informal market, where they can receive between 7% to 16% of the market value for their timber.

Viewpoints of the non-participant stakeholders
As of the current draft of this report, we have discussed our findings with 27 non-participant stakeholders. This research is ongoing and will be updated as we gain additional insights. Overall, we did receive recognition from the majority of the non-participant stakeholders that the TA constraints that we identified were issues of importance that should be addressed. Specifically, there was a recognition that the existing TA regulations have contributed to the rise of the informal timber market sector, which is a concern to many non-participant stakeholders. We found that addressing the constraints of the TA are not as simple as revising the existing policies. There are also several other existing issues that act as a hindrance to improving the livelihoods of FROs. We have summarized these issues below.

Mis-management of royalties and financial illiteracy
Multiple interviewees told us that within the formal timber market, FROs are often exploited by the landowner agents that they select to represent them in dealings with the PNGFA and the logging industry. These agents are typically selected by their clans because they have a higher level of education than the other FROs of their clan and they are multi-lingual. There are over 800 different languages spoken in PNG, along with a common language referred to as 'Tok pisin' and the English language. If the landowner agent is the only person in the clan that can act as an interpreter between the FROs and the PNGFA, they have a unique position of power. We were told that it is a widespread practice of landowner agents to use portions of the clan royalties for their own benefit. When other members of the clan ask where the money went, we were told that common reasons given by landowner agents is that they were robbed or that the Forestry Office kept the money.

We were told that financial education is a challenge in many of the rural communities. Royalties are typically quickly spent on store-bought goods, with no money put aside for long-term needs. Even if the people were interested in saving a portion of their income for future needs, approximately only 20% of the population has a bank account to safely store the money (Bakani 2018). An example that highlights the existence of financial illiteracy is the usurious money lending schemes that we were made aware of. We were told that usurious money lending is prevalent throughout the country both geographically and by income class. Interest rates quoted to us were between 30% and 50% of the loan principle, with loan time horizons typically being between one to three weeks. Some of the interviewees suggested that timber royalties should be invested into a financial instrument on behalf of the FROs that pays them dividends rather than a lump sum so that FROs will receive financial benefits over a longer timeframe. These same interviewees quickly recognized that the challenge of this approach would be selecting a financial manager that all stakeholders would trust to safeguard the investment and disburse the dividends. The existence of a lack of trust between stakeholders was brought up by the majority of interviewees.

Mis-management of the timber levies
Timber harvest levies are paid to the PNG government by FIPs conducting logging within the formal market. The levy monies collected are used to fund various

development projects. The types of levies and amount of monies collected varies with each timber harvest agreement. Research by Scudder et al. (2019b) estimated that timber levies collected in 2017 represented approximately 11.6% of the total log export values and totalled approximately 10.5 million Kina. We were told that a typical breakdown of levy expenditure is; 45% for provincial and local-level government (LLG) infrastructure and business development; 17% for reforestation and monitoring; 16% for administrative expenses; 11% for education; 6% for home construction; and 6% for spiritual activities.

Multiple interviewees expressed a concern that there is mis-management of the timber levies occurring. We were told by several interviewees that there are occurrences when levy committees use the levy funds in ways that will benefit the committee members and not the FROs. One example that we heard of in multiple instances was the abuse of the Log Export Development Levy (LEDL). The LEDL was established in 2007 to fund infrastructure development within the districts that timber harvested occurred. The National Newspaper (2017) reported that between 2007 and 2015 approximately 100.6 million Kina had been paid out of the LEDL to various district treasuries on behalf of the representative MPs, but these monies have yet to be acquitted. The lack of acquittals has led to the belief that the monies have been embezzled by those with access to the accounts for their own personal gain.

Unrecognized economic benefits provided by the logging industry to FROs

We were told that FROs also receive economic benefits from the logging companies and other private resource extraction companies that operate in rural areas. Some examples that we were given were; infrastructure development and upkeep such as roads, schools, churches, water tanks, and aid posts; increased employment opportunities; the provision of vehicular transportation to FROs for medical emergencies; and providing FROs with free mechanical maintenance of machinery such as chain saws. These are economic benefits that FROs receive that the logging industry is not compensated for and often does not get recognized for by other stakeholders. We were told my multiple interviewees that further reduction in logging industry profits to increase levies or royalties will force the logging industry out of business.

The need for extension foresters

A recurring theme that we heard during our interviews with non-participant stakeholders was the need for more extension forestry. We were told that if there was more extension forestry, foresters in the rural areas would be able to provide forestry focused training and management expertise to the FROs. We were told that prior to the Forestry Act (1991), government forestry was decentralized, allowing for more forestry personnel in rural areas. We were told that there were nurseries in each district that would give trees away to the people. The Forestry Act (1991) resulted in the creation of the PNGFA as a centralized management system that unified the 19 provincial forestry departments that were already in existence. We were told that the PNGFA currently does not have the have the funds or resources to put foresters in the rural areas continuously. The challenge this creates is that the PNGFA personnel are not able to gain the trust of FROs and build a working relationship since they are not there every day. One division of the PNGFA that was mentioned as not having adequate funding is the Community Forestry Division. We were also made aware of a Business

Development Division in the PNGFA but were told that this division is more focused on plantations and not native forest management or small-scale forest management.

4 Discussion:

The current TA harvest permit does not appropriately address the needs of the FROs and small-scale timber producers because it does not match the size of small-scale timber harvests currently being conducted, or the immediate monetary needs of the FROs. The volume of logs typically harvested with the portable sawmills is substantially smaller than the TA allotment of 5,000 m^3. The performance bond regulations of the TA are an additional hindrance to most small-scale timber producers because they do not have the financial means to adhere to them. As such, most of small-scale timber producers choose to operate within the informal market. The time required to plan for a TA and get it approved by the government can take several months and does not fit with the FROs planning timeframe, which is usually dictated by the immediate need for cash. In addition, the revenues that FROs would receive from a timber harvest under a TA permit would be much larger than their immediate cash needs. For example, if 5,000 m^3 were harvested and the average payment per m^3 of log was 15 Kina, the total payment would be 75,000 Kina. Less than 15% of the population in PNG has a bank account (Bakani 2018). In the absence of a bank account, the majority of FROs do not have a safe place to store their cash. Furthermore, the FROs would have to wait for the forest to regrow before they could conduct another harvest for their future cash needs. Non-participant stakeholders often described the situation to us as that FROs view their forests as a bank automatic teller machine (ATM) and make a withdrawal (small-scale timber harvest) periodically for immediate monetary needs.

Addressing the constraints of the TA through policy revision alone is unlikely to reduce the participation in the informal sector due to other challenges existing in the formal market system; the declining real value of timber royalties; mis-management of the royalty payments; and mis-management of the timber levies. In the informal market, FROs typically receive a larger payment per unit of timber than they would in the formal market. The FROs are also able to conduct business directly with small-scale timber producers instead of having to rely on the input/advice of landowner agents, the PNGFA, and the industrial logging companies. The immediate payments received in the informal market are also a better match to the FRO's immediate monetary needs rather than waiting for royalty payments and the assured development projects funded by timber levies that may or may not arrive as promised.

Making the small-scale timber informal market a legal and regulated formal market will likely require substantially increasing the level of extension forestry to rural areas and introducing a simplified small-scale timber harvest permit that matches harvest systems already occurring in the informal market (500 m^3 or less per annum). If informal market participants are going to voluntary move to a formal market system, there will need to be perceived benefits for making the change. Some examples of benefits that could be provided by extension foresters are; sharing of timber market knowledge; forest management training; development of forest management plans; basic forestry related financial training; access to quality seedlings of high-value species or other species of interest to FROs; and connecting FROs with reputable/ethical small-scale timber producers. Extension foresters would also be able to provide assistance with completing the necessary harvest permit applications and related forms. A drastic reduction of the bureaucratic procedural requirements of the application process would be necessary to draw participants out of the informal market.

One challenge to increasing the level of extension forestry is sourcing the funding and the required resources to outfit extension foresters. We were told that extension forestry was much more prevalent in PNG prior to the Forestry Act (1991). We are continuing to research how extension forestry was previously structured and financed to gain a better understanding of if a similar system could be used again. Later versions of this report will be updated to reflect this ongoing research.

5 Recommendations:

We have made the following five recommendations for mitigating the constraints of the current TA system and reducing the participation of the informal timber market sector. This research in ongoing and will continue to revise our recommendations as new findings are made.

- *Introduction of a new small-scale TA for domestic harvesting*. The suggested harvest allotment is for 500 m^3 per annum at a given site. The suggested application fee is 28 Kina and the suggested performance bond is 2,000 Kina to reflect the reduced harvest volume.
- *Decentralized application process to reduce processing time*. We suggest that the proposed small-scale TA be processed at the provincial level by the Provincial Forest Management Committees.
- *Increased timber royalties for the proposed small-scale TA*. We suggest that royalties for this specific permit be increased to encourage the participation of FROs and reduce FRO participation in the informal market.
- *Development of a timber sale advertisement system for the proposed small-scale TA.* We suggest that FRO timber sales be publicly advertised at the provincial or district level to registered saw millers to encourage their participation and reduce participation in the informal market.
- *Increased extension forestry*. We suggest that the number of extension foresters be increased for the purposes of; informing FROs about the benefits of the new small-scale TA; assisting the FROs in developing a harvest plan; linking the FROs to a registered miller/manufacturer; assisting the miller/manufacturer with the completion of the application process; ensuring that harvest agreements are upheld and harvesting regulations are followed; proving tree seedlings for re-forestation, and providing forestry based training and education.

6 Conclusion:

The objective of this research was to identify key constraints associated with the current TA harvest permit process that limit FRO’s access to formal timber markets and identify possible ways to improve the process. To identify these constraints, we interviewed a total of 50 stakeholders. We found that the TA processes are structured for the use of industrial logging companies and do not fit the needs of FROs or small-scale timber producers. In addition to the TA constraints, we also identified several other challenges within the formal timber market system; the declining real value of timber royalties; mis-management of royalty payments; mis-management of levies; and the financial illiteracy of FROs. The combination of these challenges has hindered the ability of FROs to improve their livelihoods by participating in the formal timber market and has resulted in many of them participating in the informal market sector. Improving the livelihoods of FROs by assisting them in accessing formal timber markets will likely require addressing all of these issues and would not be accomplished by addressing the TA constraints alone. We recommend that a new small-scale TA be introduced that better matches the timber harvest occurring in the informal market. For this proposed small-scale TA, we suggest that timber royalties be increased, and that timber sales related to this harvest permit be publicly advertised to increase the participation of FROs and small-scale timber producers. We also suggest that extension forestry be increased to aid in facilitating this system to provide management expertise and training to all stakeholders.

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Appendix A: The Timber Authority Process

Appendix A discusses each of the steps required for an individual to receive a TA.

A.1 Registration of Forest Industry Participants

Registration as a forest industry participant is the initial requirement for applying for a TA. Application for registration is stated in Section 107 of the Forestry Act. There are three requirements for becoming a registered forestry industry participant. The first requirement is that the individual applying create a legal entity, such as a business, company, or incorporated association. The second requirement is the completion of a prescribed registration form to the Managing Director of the PNG Forest Service. The third requirement is an application fee of by way of bank cheque. The fee is 275 Kina for PNG Nationals and 550 Kina for foreigners. The application processing typically takes two months to complete.

A.2 Application for Timber Authority

An application for a domestic processing TA is required to be filed by a forest industry participant. The application is referred to by the PNGFA as Form 156 (NFS 1991b). There are seven additional required attachments to the application that are referred to as schedules. Schedule 1 requires that a map and description of the project area be completed. The harvest area on the map needs to be outlined in red. Schedule 2 requires the commencement date that the TA will begin. Schedule 3 requires the expected annual harvest volume, which is not to exceed 5,000 m^3. Schedule 4 is the performance bond, which requires the forest industry participant to submit 20,000 Kina to be released on the authorisation of the Managing Director of the PNG Forest Service after the holder of the TA has submitted a completion report and has satisfied the terms and conditions of the TA. Schedule 5 discusses the standard conditions that must be met by the holder of the TA to receive the performance bond monies. These conditions are listed below:

- The holder must maintain the validity of their registration as a forest industry participant.
- The holder must not exceed a harvest volume of 5,000 m^3.
- The harvest area must exist within a 10-kilometre radius.
- If the holder applies for another TA, they must disclose the existence of any previous TAs.
- The holder must not export any of the timber harvested under the TA.
- The holder must follow the PNG Logging Code of Practice and comply with the key standards of selection logging.
- The holder is not allowed to make food gardens, hunt, or fish within the project area or areas adjacent to it.
- The holder must not fell, cut, damage, or remove; any trees declared as reserve trees under Section 4 of the Forestry Act, any species of trees or plants specified or marked by the landowners in accordance with the Sales and Purchase Agreement, and any timber or other forest products existing within specified cultural areas, burial grounds, gardens, or other reserve areas in accordance with the Sales and Purchase Agreement.
- The holder must make payment for the timber harvested, to the landowners as royalties and to the PNGFA as levies. The royalty payments to the landowners must be made monthly and be based on the log scale recordings.
- The holder must construct all roads and bridges required for the operation and maintain them during the operation.
- The holder cannot charge the public for using these roads and bridges.

- The holder must not erect any buildings or fixtures within the project area without consent of the landowners.
- Any buildings or fixtures that are erected within the project area must be removed within 90 days from the expiration or cancellation of the TA.
- All the timber harvested must be scaled and recorded in accordance with direction given by the Managing Director of the Forest Service or in accordance with PNGFA's directions for log scaling.
- The holder must carry out all the harvest operations and not sub-contract the work other than by the employment of individual contract workers on piece-rates.

Schedule 6 discusses the royalty payments that the holder agrees to pay the landowners, which must not be less than those required by the National Forest Service. The minimum required royalty rates vary by species and are categorized into four groups, with group 1 representing the most sought-after export species. Within group 1, three tree species have distinct royalty rates; *Intsia bijuga* (Kwila) is 35 Kina per m^3, *Palaquium* spp. (Pencil cedar) is 20 Kina per m^3, and *Dracontomelon dao* (Walnut, PNG) is 20 Kina per m^3. The remaining group 1 species have a fixed-rate of 15 Kina per m^3. All the remaining species in groups 2, 3, and 4 have a fixed-rate of 10 Kina per m^3. These fixed-rate royalties have been in effect since 1 March 2008 and are detailed on Form 221 (NFS 2008). Schedule 7 lists any additional requirements made by the Provincial Forest Management Committee. In addition to application of the timber authority, the forest industry participant is also required to submit two additional forms to the Managing Direction of the PNGFA. These are discussed in sections A.21 and A.22.

A.21 Timber Authority Verification of Ownership and Consent of Landowners

The verification of ownership and consent of landowners is listed as Form 165 (NFS 1991c). This form needs to be filled out by every clan agent, incorporated land group, or individual having ownership rights over timber or forest products within the proposed harvest area. This form must be signed in the village where the landowners live and be witnessed by a Village Court Magistrate or land mediator. Everyone that signs Form 165 needs to be given a copy of the application for the TA.

A.22 Sales and Purchase Agreement

The sales and purchase agreement is listed as Form 166 (NFS 1991d). This form is essentially a sales contract that lists the names of all parties involved in the agreement and the terms of the agreement. This form is divided into four sections or Schedules. Schedule 1 requires all the landowners to provide their names and signatures. Schedule 2 requires a map diagram of the clan area with the clan boundary in red and any cultural areas to be excluded from the harvest outlined in green or blue. Schedule 3 lists the agreement on royalty payment amounts, which cannot be less than those required by the National Forest Service. Schedule 4 is a list of any excluded areas if they cannot be shown on the map.

A.3 Additional Documents related to the Timber Authority

After the FIP has submitted the TA application, performance bond, and the other required documents, additional actions occur within the PNGFA. If the Managing Director of the Forest Service is satisfied with the application, they will refer the application to the Forest Management Committee of the appropriate Provincial Forest on Form 168 (NFS 1991e). If the Provincial Forest Committee is not satisfied with the application the forest industry participant will receive a notice of rejection on Form 169 (NFS 1991f). If the Provincial Forest Management Committee is satisfied with the application, they will send a recommendation to the Chairman of the Committee on Form 170 (NFS 1991g). The Chairman of the Committee then sends a notice of intention to grant a TA to the Forestry Board on Form 171 (NFS 1991h). If the Forestry Board gives their consent to grant the TA they give notice of their consent to the Chairman of the Committee on Form 172 (NFS 1991i). The Chairman of the committee will then notify the forestry industry participant applicant that a TA has been granted to them on Form 155 (NFS 1991a). At any time after the TA has been granted to a forest industry participant and it is found that the holder of the TA has been convicted of an offense against the Forestry Act or a law other than the Forestry Act, the Chairman of the Committee sends notice of a cancellation of the TA to the holder on Form 173 (NFS 1991j).

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Addressing small-scale forestry informal markets through forest policy revision: A case study in Papua New Guinea

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A B S T R A C T

Informal markets for timber harvested from small-scale and community forests can be vital to the development of rural economies and the empowerment of communities in many tropical developing countries. However, legal status of these markets is often uncertain, and this can prevent smallholders accessing government support and gaining access to financing. In Papua New Guinea (PNG), knowledge about the small-scale forestry informal market is limited, since the government does not have the resources to track or regulate it. Casual observation suggests that the market is comprised of individuals or businesses using portable sawmills for the commercial production of rough-sawn lumber. We used a descriptive case study approach to understand the processes of the forest-based informal market and to determine if there are specific forest policy/regulation features that are leading to informal market activities. We found that the forest policies/regulations are driving participation in the informal market because of vague policy definitions and the existing timber harvest permits being more suited to industrial-scale harvests and inappropriate to the needs of small-scale forestry participants. The current distribution of forest resource rents in the informal market is skewed in favour of small-scale timber product manufacturers, resulting in the forest resource owners receiving an inequitable share of the timber value. We estimated that the log harvests occurring in the informal market could be in the order of 560,000 cubic meters (m^3) annually, which is equivalent to 17% of PNG's log exports in 2017. The estimated size of this market highlights the large unmet economic potential occurring in the small-scale forestry sector. We recommend that the existing harvest regulations be revised to include a new small-scale harvest permit of 500 m^3 per site per annum, along with improved timber royalty rates for the resource owners. In addition, we recommend increased government support be provided through extension foresters to improve the sustainability and productivity of the small-scale forest products market.

1. Introduction

There are approximately 60 million Indigenous people living within the world's tropical forests, with an additional 400–500 million people that are directly dependent on tropical forest resources for their livelihoods (White and Martin, 2002). Multiple terms have been used to describe forest management by Indigenous people. Small-scale forestry is a term that means different things in different countries, but generally refers to a multiple-use management style and a managed land area that is small relative to industrial forest estates (Harrison et al., 2002). Community forestry has been described as a generic term that refers to the involvement of locally resident groups in aspects of forest management, which includes native forests, small-scale plantations, fruit trees, and rubber trees (Baynes et al., 2015). The business organizations that are developed for these types of forest management are often referred to as small to medium forest enterprises (SMFEs), which are entities that engage in forest-based activities and employ a relatively small number of people (1–250) (Kozak, 2007). These jobs are an important source of income to rural communities. The global annual economic contributions of SMFEs are estimated at over $130 billion USD (Mayers, 2006).

A review of the literature on community-based forestry and forest-based SMFEs shows that governmental polices and regulations can have a significant impact on the success or failure of these operations. An enabling regulatory framework is one of the key factors influencing the success of community forestry groups in tropical countries (Baynes et al., 2015). Similarly, Gilmour (2016), found that multiple complex compliance procedures creates significant impediments to smallholders engaged in community forestry. Similarly, in a study on community engagement in natural resource governance, Ojha et al. (2016) found

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that the forestry focused regulatory framework has made it difficult to develop community-based operations and enterprises because the regulations are either not relevant or present demanding challenges for small-scale operators. Macqueen et al. (2012) found that it is difficult for forest-based SMFEs to succeed even when the forest communities own the land, if the government has failed to develop legislation that provides easy access to commercial rights of the land. When forest communities do not have accessible commercial forest rights, forest based SMFEs typically deteriorate to subsistence or informal market activities (Macqueen, 2012).

Globally, it has been estimated that 140 million people are involved in informal forestry markets that empower local communities through increased wage earnings and assist with community development by providing forest products that can be used for local construction projects (Mayers, 2006). While these informal markets can empower communities, the questionable legality of informal markets can prevent them from reaching their full potential. Since informal market participants are technically operating outside the jurisdiction of the local forestry authority, their ability to gain access to finance and technical support is hindered (Hoare, 2016). Furthermore, by avoiding government taxes and licensing requirements, governments view them as incompatible with forest industry development programs and not a priority for support (Hoare, 2016). Because access to finance is limited, many informal market operators often use old or outdated equipment that may be inefficient or unsafe to operate (Hoare, 2016). This reduces their productivity and the production of processed wood products that command higher sales prices than rough-sawn lumber. Because information about the volume and value of forest products which are produced by these operations is not reported to or collected by most governments, it is difficult to ascertain the number of market participants, causal links between the participants, and the destination of the timber or the timber products at the country level.

Assisting forest-based informal market SFMEs to reach their full potential requires an in-depth understanding of the informal market participants, the causal links between the participants, and an understanding of how government policies and regulations impact the actions taken by participants. We hypothesise that the existence of forest-based informal market activities can be linked to specific forest policy/regulation features. By identifying the specific policy/regulation features that lead to informal market activities, it will be possible to identify policy changes that can aid in bringing these activities into formal markets. With uncertainty around the legal status of forest-based SMFEs removed, participants would have improved access to financing and the opportunity to reach their full potential.

We conducted a descriptive case study on the forest-based informal market in Papua New Guinea (PNG). The total size of PNG's informal economy has been estimated to be approximately 36% of the country's total economic output (Schneider et al., 2010). The contribution which is derived from informal forest harvesting and wood processing is unknown, as the PNG government does not focus on regulating or tracking this market. The goal of our study was to understand the processes of the forest-based informal market and to determine if there are specific forest policy/regulation features that are leading to informal market activities. Our specific research objectives were to identify; what are the forest policies/regulations that impact forest-based SFMEs, who are the informal market participants; how does the informal market function; and to determine why do participants choose to operate within the small-scale forestry informal market? The results of this analysis has broad relevance to not only PNG but many other developing countries elsewhere in the tropics.

In the next section of this paper, we provide background information on small-scale forestry based SMFEs in PNG. This is followed by a discussion of the methods we used to undertake this analysis, our case study results, discussion, and conclusion. Our discussion section includes recommendations for improving the legality of the informal market.

2. Background information: small-scale forestry SMFEs in PNG

In Papua New Guinea (PNG), there are approximately 29 million hectares of forest, of which approximately 97% are held under customary land ownership by Indigenous communities (PNGFA, 2009). Small-scale forestry and the associated SMFEs in PNG have primarily focused on individual tree harvesting and milling with portable sawmills. Portable sawmills were first introduced in PNG in the 1970s by church groups and non-governmental organizations (NGOs) to assist in community development (Bun and Scheyvens, 2007; Holzknecht et al., 2012). Beginning in the 1990s, multiple NGOs began facilitating multiple communities throughout the country in small-scale forest management operations referred to as eco-forestry, which utilized portable sawmills to produce sustainably certified rough-sawn lumber for export (Scudder et al., 2018). NGO led eco-forestry operations ceased by 2012, primarily due to challenges related to NGO funding and difficulties of the portable millers in achieving quality and quantity production targets (Scudder et al., 2018).

While portable sawmill enterprises in PNG can be profitable if high productivity and high lumber recovery targets are achieved, along with operations being located near markets, multiple studies have found that mill production and lumber recovery targets usually have not been met by communities (Keenan et al., 2010, Grigoriou et al., 2011; Scudder et al., 2019b). Furthermore, achieving profitability required a selective focus of the most valuable timber species, which is likely to lead to an over-harvesting these species (Scudder et al., 2019b). Portable sawmills continue to be used by communities and SMFEs throughout PNG to harvest and mill lumber on clan lands. However, little is known about the number of operators or the harvest volumes associated with this sector or the destinations of the timber, as the PNG government does not have the resources to track or regulate this sector. Anecdotal evidence based on the many trucks transporting portable sawmills and milled lumber throughout the country suggests the existence of a large informal market associated with small-scale timber harvests.

3. Methods

We used a case study methodology to investigate the informal timber market. A mixed methods approach was used for data collection, which included interviews, personal observations and documents. Data collection occurred during multiple trips to PNG during years 2016–2018. Our case study used a single-case design with multiple sources of analysis following methods outlined by Yin (2009). In this paper, we refer to the sources of analysis as informal market participants. We had a total of 19 informal market participants that were classified into three primary groups; 1) forest resource owners (FROs), 2) portable saw-millers, and 3) small-scale manufacturing businesses. The saw-millers only produced rough-sawn lumber. The manufacturing businesses processed rough-sawn lumber into other wood products, such as dressed structural lumber, mouldings, tongue & groove (T&G) flooring that commanded a higher sales price per unit relative to the rough-sawn lumber. We conducted interviews with each of the informal market participants. In some instances, the informal market participants were individual people and in other instances the participants were comprised of multiple people. The total number of informal market participant interviewees was 23 (Table 1).

We also interviewed an additional 15 non-participant stakeholders that were familiar with how the informal small-scale forestry market functioned. These fifteen interviewees were employees of the PNG Forest Authority (PNGFA), the Foundation for People and Community Development (FPCD), the Timber and Forestry Training College (TFTC), and an agricultural equipment distributor named Farmset (Table 1). The PNGFA is the government agency tasked with the management of PNG's forest resources. The FPCD is a Non-Governmental Organisation (NGO) that has implemented small-scale forestry projects involving portable sawmills in communities in PNG (Scudder et al., 2018). The

Table 1
Descriptions and number of interviewees.

Informal market participants	Participants	Interviewees
Forest Resource Owner (No mills)	2	3
Forest Resource Owner (With mills)	4	5
Sawmill owner only	6	6
Small-scale manufacturing business (No mills)	1	1
Small-scale manufacturing business (With mills)	6	8
Total	19	23
Non-participant stakeholders	Organizations	Interviewees
PNG Forest Authority	1	4
Foundation for People and Community Development	1	3
Timber and Forestry Training College	1	7
Farmset (Portable sawmill distributor)	1	1
Total	4	15

TFTC provides vocational and technical training in use of portable sawmills and in value-add wood product processing equipment. Farmset is a distributor of chainsaws and portable sawmills with nine branches through-out PNG.

3.1. Data collection

Documents collected included governmental reports/documents, technical reports produced by other research organizations, wood product sales price sheets produced by the manufacturing businesses, peer-reviewed journal articles, and newspaper articles. Thirty-eight people were interviewed between years 2016 to 2018. The fifteen non-participant stakeholders were initially interviewed because they were familiar with the informal market. The remaining twenty-three interviewees were with FROs, saw millers, manufacturing business owners, or manufacturing business employees associated with the 19 informal market participants. These interviewees were selected with assistance from the non-participant stakeholders.

The 19 informal market participants were located within the Momase Region of PNG, which comprises the East Sepik, Madang, Morobe, and West Sepik Provinces. The exact geographic location and names of the 19 informal market participants and associated interviewees have been omitted to ensure confidentiality. The initial interviews with non-participant stakeholders helped us develop an interview protocol which was designed to identify the functional operations of the 19 participants. The questions asked were; where timber/wood products were sold and to whom; the type of equipment used to harvest the trees and process the timber; the cost of production; how sale agreements were arranged; volumes produced; prices received from sales; their perceptions of the forest policies; why participants choose to operate without the necessary permits; and their perceptions on the size of the informal market. The interview format was similar for all interviewees. The interviews were primarily conducted by the first author, with participation also provided by the third author and a former research forester of the Tropical Forestry and People Research Centre. Hand-written notes were taken by the three interviewers during all interviews. The length of the interviews varied between 30 min and one hour. At least one non-participant stakeholder was present at all the interviews to provide their post-interview perspective to the interviewer.

3.2. Data analysis

We began our data analysis by describing the forest policies that impact small-scale timber harvest operators. This description was based on data collected from the PNG Forest Policy Act (1991) and multiple National Forest Service documents (NFS 1991a; NFS 1991b; NFS 1991c). Interview data was compiled into a case study 'database' using Microsoft Excel Software. To improve external validity, we used replication logic in the selection of our interviewee sources to ensure that responses would be similar (Yin, 2009). Our study had a total of 19 informal market participants; six were FROs, six were saw-millers, and seven were small-scale manufacturing businesses. To address internal validity, we conducted pattern recognition to identify recurring trends in our interview data (Yin, 2009). We placed our interview data into a database by arranging the rows of the database to represent the individual participants and the columns of the database to represent the questions asked to the interviewees. When we identified similar responses to interview questions we calculated the percentage of responses relative to the total. We also assessed patterns within the case study groups by filtering the data for; FROs with no mills, FROs with mills, saw-miller only, small-scale manufacturing business with no mills, and small-scale manufacturing businesses with mills. We triangulated the interview data by collaborating it with additional evidence in the documents we collected and by having non-participant stakeholders review drafts of our case study. We used the identified patterns and triangulated data to provide a description of the informal market participants. We estimated the size of the informal market with data collected from technical reports, a portable mill number survey, and annual production data of portable mills gathered during interviews.

We conducted a resource-rent-capture analysis to compare the values paid/received by the informal market participants at four stages of the value-chain; standing trees prior to harvest; rough-sawn lumber at the harvest site; rough-sawn lumber delivered to the manufacturing businesses; and finished product located at the manufacturing businesses. The analysis was performed with data collected during interviews with the 19 informal market participants and the non-participant stakeholders, as well as sales price sheets for finished products collected from the manufacturing businesses. We averaged the market values of the wood products produced at each value-chain stage. The number of assorted products sold by the manufacturing businesses typically exceeded 100, due to multiple species, product types, dimensions, and whether or not the timber have been chemically treated. For this analysis, we selected four products, which we were informed were timber products with high demand. These products were; tongue and groove (T &G) flooring (*Intsia bijuga* 95 × 20 mm); treated architrave moulding (Mixed hardwoods 70 × 20 mm); treated structural lumber (Mixed hardwoods 100 × 50 mm); and treated weatherboard (Mixed softwoods 145 × 20 mm). Since the sales transaction between FROs and saw-millers were typically paid as Kina per m^3 of lumber, we converted the lumber price into pre-harvest log values. To do this, we assumed a lumber recovery rate of 45% and applied this to the government royalty rates per m^3 of log (Table 1). Since the sales prices for finished timber products for the manufacturing business were listed as price per lineal meter, we converted the prices to m^3 of lumber product.

For the T&G flooring product (*Intsia bijuga* 95 × 20 mm), we also compared the values received by the informal market participants to the cumulative cost of production at each stage of the value chain. The production costs were collected during interviews with the 19 market participants and from non-participant stakeholders. These costs were averaged for each stage of the value-chain. The production costs included royalties paid to FROs, felling and transporting the log to the portable mill, milling the lumber, transporting the lumber to the manufacturing business, sorting/grading the lumber, machining the lumber into flooring, and overhead costs per m^3 of flooring produced for the manufacturing business. In addition, we assessed if the stumpage prices paid to FROs equate to an equitable portion of timber resource rents. Timber resource rents are defined as the residual value of round-wood produced after subtracting the costs of round-wood production (Gray, 1983). To identify what could constitute an equitable rent distribution to FROs, we compared data from the most recent logging cost study in PNG produced by FORTECH (1998), to the average export value of round-wood in PNG for the same year as stated by the ITTO (2018). All the price data that we present is in PNG's currency, which is called Kina (PGK). The PGK exchange rate to USD is

0.2970 (BPNG, 2018).

4. Results

4.1. Existing forest policies that impact small-scale timber harvests in PNG

In the amended PNG Forestry Act (1991), there are no sections that clearly define the legal requirements for timber harvests that are less than 500 cubic meters (m^3) per annum. Interviews with non-participant stakeholders revealed that there is a general understanding that FROs can harvest up to 500 cubic meters (m^3) per annum for personal uses without a harvest permit issued by the PNGFA, but the harvested timber cannot be used for commercial activities. However, what comprises 'commercial activities' is not clearly defined by the Forestry Act (1991) or universally agreed upon. If FROs choose to harvest timber specifically for commercial activities, they must comply with a number of requirements. The first requirement is for an individual to register as a 'forest industry participant' (FIP). The PNG Forestry Act (1991) defines an FIP, as, "Any person engaging in, or intending to engage in, forest industry activities (otherwise than as an employee of a forest industry participant or in the capacity of a common carrier) where the timber harvested, bought, sold or arranged or procured to be sold or purchased, by that person in a calendar year exceeds 500 m^3 in volume." The registration process requires the creation of a legal business entity, a completed registration form delivered to the Managing Director of the PNG Forest Authority (PNGFA), and an application fee of 100 Kina by way of bank cheque (Forestry Act, 1991).

To obtain a small-scale commercial harvest permit, the second requirement is for the registered FIP to apply for a Timber Authority (TA) harvest permit for domestic processing[1] . A TA for domestic processing allows a FIP to harvest up to 5000 m^3 from land occurring within a 10-km radius over the duration of one year (Forestry Act, 1991). The application process requires a map and description of the proposed harvest area, the harvest commencement date, the expected harvest volume, a 275 Kina application fee, and the submission of a 20,000 Kina performance bond that is only released after the submission of a harvest completion report and verification that all terms and conditions of the TA were met (NFS, 1991a). In addition to the application of the TA for a harvest permit, the FIP is also required to submit two additional forms to the Managing Director of the PNGFA. The first form is a verification of ownership and consent of landowners is listed as Form 165 (NFS, 1991b). This form needs to be completed by every incorporated land group, or individual having ownership rights over timber or forest products within the proposed harvest area. This form must be signed in the village where the landowners live and be witnessed by a Village Court Magistrate or Land Mediator. The second form is a Sales and Purchase Agreement and is listed as Form 166 (NFS, 1991c). This form is a sales contract that provides the names and signatures of all parties involved in the agreement and the terms of the agreement. After all the required documents and fees have been submitted to the PNGFA Managing Director, the application is processed. Non-participant stakeholders revealed that the time required to process an application is typically several months.

The Forestry Act (1991) requires that persons or logging companies operating with a TA make royalty payments to the FROs for all timber harvested. The royalty payment amounts are minimum fixed rates and vary between 10 and 35 Kina (PGK) per m^3, depending on the tree species. This is equivalent to \$2.97 and \$10.40 in 2018 USD using a conversion rate of 0.2970 Kina per 1.0 U.S. Dollar (NFS, 2008; BPNG, 2018) (Table 2). The timber species in PNG are categorized into four groups, with Group 1 representing the most sought-after species. The fixed-rate royalties have been in effect since 1 March 2008. Prior to this date, the minimum fixed-rate was 10 Kina (PGK) per m^3 for all species, which was set by the PNG Forestry Act (1991).

[1] There are five types of TAs; domestic processing, road clearing, agricultural conversions, other forest products, and plantations. The TA for domestic processing is the most appropriate existing permit for small-scale operators.

Table 2
PNG timber royalty rates per m3 (2018 PG K and USD).

Group/Species	PGK	USD
Group 1		
Intsia bijuga	35.00	$10.40
Palaquium spp.	20.00	$5.94
Dracontomelon dao	20.00	$5.94
Remaining Group 1 species	15.00	$4.46
Groups 2, 3 and 4 species	10.00	$2.97

4.2. Description of informal market participants

The informal market was separated into three groups; 1) FROs, 2) saw-millers, and 3) manufacturing businesses. One third of the FROs that we interviewed owned their own sawmills and harvested timber from their own lands. The remaining FROs interviewed sold their timber to individuals or manufacturing businesses that owned their own portable sawmills. Six out of the nineteen market participants only operated portable sawmills. We found that these six participants typically arranged harvest agreements with relatives that owned forest resources. The saw-millers sold the lumber they produced to manufacturers that further processed the rough-sawn lumber. We found that the saw millers had limited knowledge of rough-sawn lumber dimensions and species desired by the manufacturers. The saw millers had to frequently visit the manufacturing businesses to ascertain the current demand for various species and lumber dimensions.

All the manufacturing businesses purchased rough-sawn lumber from portable sawmill owners. Six of the seven manufacturing businesses also owned their own portable sawmills and also entered into harvest agreements with FROs. None of the manufacturing businesses were owned by FROs. The rough-sawn lumber milled by the manufacturing businesses was transported back to the business shop to produce further processed wood products. The most sought-after species of the manufacturing business were *Celtis* spp., *Dracontomelon dao, Intsia bijuga, Pometia pinnata, Pterocarpus indicus, Terminalia* spp., and *Vitex cofassus.* The remaining species purchased were aggregated into groups and referred to as 'Mixed hardwoods' or 'Mixed-softwoods.' The most common products produced were dressed structural lumber, T&G flooring, decking, weatherboard, and mouldings. Other products produced were furniture and coffins. The additional processing generally involved the use of moulding machines and thicknessers/planers, most of which were not of high quality. Three of the seven manufacturing businesses provided lumber dressing services to individuals that only owned a portable mill. The finished products were typically sold to hardware stores, construction companies, churches, schools, and the general public. These manufacturing businesses have operated in both the informal and formal markets in that they purchased raw materials from informal market operators, may or may not have paid taxes themselves, and have sold their products to individuals/businesses that also may or may not have paid taxes.

4.3. Commercial transaction arrangements between informal market participants

There were three types of arrangements that portable mill owners used when harvesting FRO timber. The most common arrangement was referred to as the '2 for 1 agreement.' The 2 for 1 agreement allocated two thirds of the milled lumber to the mill owner and one third of the milled lumber to the FRO. Usually, this arrangement was applied to the volume (m^3) of lumber produced, but sometimes it was based on number of trees harvested and milled. The FROs were typically given the opportunity to sell their portion of the lumber to the sawmill owner at an agreed rate. The 2 for 1 arrangement was used by 50% of the informal market participants for timber purchases[2] . The remainder of timber purchases involved a set-rate paid to the FRO for the volume (m^3) of lumber produced. These set-rates varied by species. In some cases, only the A grade[3] lumber was purchased with the B grade lumber left at the harvest site for the FROs. We were informed that the set-rate arrangement was sometimes calculated for the volume (m^3) of logs harvested following the government royalty rates (Table 1), but FROs usually preferred the set-rates for volume of lumber produced. The final milling arrangement made between FROs and portable mill owners was a service fee for the volume in m^3 of lumber produced. Under this arrangement, the FROs kept all the lumber and paid the portable mill owner for services rendered.

4.4. Reasons FROs choose to sell their timber

FROs decided to sell timber to obtain cash to be used for one of five main purposes: school fees; store bought goods; ceremonies; to build a home; and for Christmas celebrations. School fees were the most common response, being mentioned by 53% of the informal market participants and corroborated by six of the non-participant stakeholder interviewees. This was initially misleading, because the PNG government passed legislation for Tuition Fee Free (TFF) education policy in 2012 (DOE, 2012). The purpose of the TFF policy was to abolish school fees for elementary and primary students, reduce fees for secondary students, and devolve the responsibility of fiscal management from the central government to the local schools and the district administrations. This policy also banned schools from charging additional fees to increase access to education for impoverished families. However, distribution of TFF subsidy funds from the central government to schools were often late or not able to cover all the school's expenses due to increased student enrolment (Paraide, 2015 and Walton, 2018). Research on educational attainment in PNG has found that 50% of households with school-aged children had difficulty in sending at least some of their children to school and only a small number of families did not pay any school fees (Ryan et al., 2017). Interviews with non-participant stakeholders revealed that the schools adapted to the lateness or shortage of TFF subsidies by continuing to charge fees under a different name, such as 'project fees.' The PNG Education Plan 2015–2019 projected that parent-paid project fees would range from 145 to 178 Kina per student during years 2016 to 2019 (DOE, 2016). An online article by the PNG Education News Website (PNGENW, 2018), discussed the increase of project fees in the East New Britain Province for years 2018 to 2020. The fees were increased to 150 Kina for elementary students (Grades 1 & 2), 300 Kina for primary students (Grades 3–8), 1000 Kina for secondary students (Grades 9–12), and 800 Kina for technical and vocational school students. The article indicated that 60% of the fees were due upon enrolment, with the remainder due by the second term. Interviews with non-participant stakeholders revealed that school enrolment occurred during January. The non-participant stakeholders also explained to us that the term 'school fees' is often used to describe all expenses related to school; the actual school fees, project fees, stationary, uniforms, and transportation to school.

The second most common reason that FROs sold their timber was to get money for the purchase of store-bought goods, which was mentioned by 42% of the informal market participants. Store-bought goods refer to consumables that FROs cannot provide for themselves, such as clothing, packaged rice, and canned meats. The remaining reasons mentioned by the cases as reasons that FROs sold their timber were ceremonies (21%), home construction (16%), and Christmas celebrations (11%). Ceremonies were typically referred to as weddings and funerals. Timber sold for home construction was either the 2 for 1 arrangement to provide FROs with lumber for construction, or the sale of timber to provide cash for the purchase of other construction materials. One of the FROs we interviewed was in the process of building a new home. We were told that the non-lumber home construction materials that he needed to purchase were nails, plywood, metal siding, roofing materials, doors, windows, and window screens. The additional cost to purchase these materials and hire a carpenter was approximately 7500 Kina. Money needed for Christmas celebrations was for the purchase of food to be shared with family members.

4.5. Reasons why portable sawmill owners conduct harvests without a TA

We found that all 19 informal market participants had been involved in commercial timber harvests without a TA harvest permit, and only two of the participants had ever acquired a TA and 50% of the participants that were not manufacturing businesses were even aware of the PNGFA TA regulations. Those that were aware of the TA regulations indicated that FROs were not concerned about government regulations because they owned the land and would use it in any way they chose. Another common reason given for not applying for a TA was the requirement of the 20,000 Kina performance bond. None of the sawmill operators that were aware of the TA regulations had the financial means to pay the bond. This challenge has been identified by others and included as part of a policy brief to the government (Bun, 2012).

Additional reasons for not applying for a TA were that the volumes harvested by all the portable sawmill owners were substantially lower than the TA harvest allotment of 5000 m^3. We found that the majority of saw millers produced less 100 m^3 of lumber annually. Assuming a recovery rate of 45%, this equates to less than 225 m^3 of logs harvested. Only two of the saw millers that were not also manufacturing businesses produced an annual volume that was greater than 300 m^3 of lumber. With a recovery rate of 45%, this equates to less than 670 m^3 of logs harvested. One of the FROs we interviewed told us that using the TA harvest permit was problematic because there is an expectation by the FROs that 5000 m^3 will be harvested. If production targets were not achieved, which was usually the case, it resulted in disappointment and often conflict.

Two of the manufacturing businesses owned multiple mills and were capable of milling much larger volumes of lumber. However, they only conducted harvests at sites owned by individual families to avoid payment distribution conflicts that were common on sites owned by multiple families or clans. We were told that the individual family harvest sites were typically between 20–50 hectares and not able to supply 5000 m^3 of logs. We estimated that if a sawmill owner operating one mill could secure an agreement with a family that had forest land capable of supplying 5000 m^3, it would take 1250 days to complete the harvest and milling, assuming a daily log input of 4 m^3. This is well beyond the one-year timeline of the current requirements of the TA and would require more than six portable sawmills to reach the 5000 m^3 production target, assuming 200 operating days per year and 4 m^3 of log input per day.

4.6. Size of the informal market and the sourcing of portable sawmills

The size of the informal market is difficult to quantify because the exact number of portable mills that are operating and the volumes of lumber produced on average by these mills is unknown. A portable sawmill survey conducted in 1995 estimated that there were 2500 operating portable mills throughout the country but had little information on volumes produced (FPCD, 1995). A technical report by Jenkin (2016), suggested that approximately 4000 portable sawmills have been imported, with approximately 2000 currently operational. Of

[2] This calculation did not include the four FROs that owned their own mills and harvested their own timber.

[3] Non-participant stakeholders defined A grade lumber as being of higher quality than the B grade due to reduced imperfections such as knots, wane, checking, or warping and cupping of the lumber.

Table 3
Assumptions used to estimate size of the informal market.

Mill operator production	Number of mills	Daily lumber output (m^3)	Annual days of operation	Annual lumber output (m^3)	Recovery rate
Low	1000	1.0	50	50	35%
Low-moderate	1000	1.5	67	100	40%
Moderate	100	1.5	200	300	45%
High	100	2.0	250	500	50%

Table 4
Estimated size of the informal market (m^3 of log input and m^3 of lumber output).

Mill operator production	Total log inputs (m^3)	Total lumber outputs (m^3)
Low	142,857	50,000
Low-moderate	250,000	100,000
Moderate	66,667	30,000
High	100,000	50,000
Total	559,524	230,000

the 2000 operating mills, it is estimated that approximately 100 to 300 operate on a full-time basis (Jenkin, 2016). Two of the manufacturing businesses indicated that their mills produced an average of 2 m^3 of lumber per day and sought to operate 250 days a year, weather allowing. Two of the saw millers said they operated full-time and produced an average of 300 m^3 of lumber per year. Five of the saw millers indicated they produced between 50 and 100 m^3 of lumber per year. Interviews with non-participant stakeholders revealed that lumber recovery rates typically varied between 35% and 50%, depending on the skill of the operators. Using this data, we estimated the total volume of log inputs and lumber outputs of the informal market. Our assumptions on which the estimates are derived are presented in Table 3 and the results are presented in Table 4. Our estimate indicates that the total volume of logs harvested annually within the informal market could be in the order of 560,000 m^3 and the total volume of lumber produced in the order of 230,000 m^3. This estimated log volume is equivalent to approximately 17% of the total logs exported from PNG in 2017 (SGS, 2018).

A non-participant stakeholder employed by a portable sawmill distributor indicated that portable sawmills are evenly purchased by businesses, families, and politicians. An additional twelve non-participant stakeholder interviewees corroborated that donations to FROs by politicians are a common way that that FROs and communities receive portable saw mills. We were told that funding for these donations typically originated from Provincial and District Services Improvement Programme (PSIP) and (DSIP). The PSIP fund annually allocates five million Kina to each of the provinces. The fund is managed by the Joint Provincial Planning Budget Priority Committees, which are typically chaired by the governors of the provinces (Howes et al., 2014). The DSIP fund annually allocates ten million Kina to each of the 89 electorates in PNG and are managed by the Joint District Planning Budget Priority Committees, which are typically chaired by the Members of Parliament of the electorate or district (Howes et al., 2014). We found 14 newspaper articles to corroborate this finding (National, 2012, 2013a, 2013b, 2014a, 2014b, 2014c, 2014d, 2014e, 2015a, 2015b, 2016a, 2016b, 2016c and Muri, 2014). According to these articles, more than 87 portable mills were gifted by politicians between years 2012 and 2016. Approximately 85% of the articles said that the primary purpose of the donations was for the construction of homes. Secondary purposes were for additional income generation and the construction and maintenance of churches, classrooms, aid posts, bridges, and police houses. Interviews with non-participant stakeholders revealed that the donation of mills by politicians can sometimes be used as a political bargaining tool, with mill donations contingent on the politician receiving enough votes to win an election. Our non-participant stakeholders explained to us that the portable sawmill distributors in PNG are not regulated and can sell mills to anyone able to pay for them. As such, they are enabling the growth of the informal market (Fig. 1).

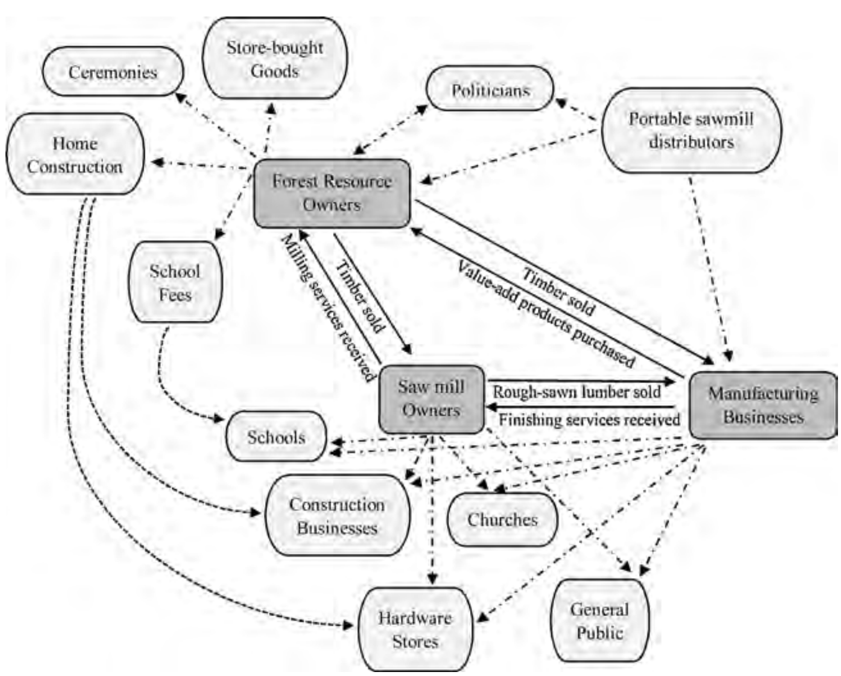

Fig. 1. Relationships between informal market participants and flow of products/services.

Table 5
Comparison of prices paid by product/species at various stages of the value-chain (PGK per m^3).

Value-chain stage	T&G flooring (*Intsia bijuga*)	Treated moulding (Mixed hardwoods)	Treated structural lumber (Mixed hardwoods)	Treated weatherboard (Mixed softwoods)
Log standing on the stump	68	43	43	20
Lumber at harvest site	150	135	135	135
Lumber delivered to business	1058	750	750	750
Finished product at business	4702	3352	2133	2667

4.7. Cost and revenues paid/received by informal market participants

The greatest value-adding for all species occurred in the fourth stage after the rough-sawn lumber was further processed (Table 5). The species with the highest price paid at all stages of the value-chain was *Intsia bijuga*. Our comparative analysis between the prices paid and cumulative production cost of T&G flooring indicates that prices paid to FROs at the second stage of the value chain are quite low, but then experience substantial growth at the third and fourth stages of the value-chain. At stage two, the average price paid was 61% less than production costs, but in stages three and four the prices paid were 56% and 522% larger than the cumulative production costs (Fig. 2). The substantial increase in price paid relative to cumulative cost of production at the fourth stage of the value-chain highlights the potential profitability that the manufacturing businesses gain by making investments in additional processing equipment.

We found that the stumpage prices paid to FROs for *Intsia bijuga* is equivalent to a timber resource rent of 9% of the formal export market value based on log export market data produced by SGS (2018). The SGS (2018) data indicated that the average export value of an *Intsia bijuga* log was 772 PG K per m^3 in 2017. By comparison, we estimated that an equitable timber resource rent would be approximately 36% of the formal market value. The logging cost analysis by FORTECH (1998) estimated that the average total logging cost (includes operations, camps/head office, overhead, and export taxes), was \$108 per m^3 (expressed in 1997 USD) (FORTECH, 1998). The average export value of non-coniferous tropical round-wood in PNG in 1997 was \$168 per m^3 (expressed in 1997 USD) (ITTO, 2018). If the FROs had been paid the equivalent of 36% of the formal market value for *Intsia bijuga* harvested and milled on their lands, the price received for rough-sawn lumber would have been approximately 618 PG K per m^3 rather than 150 PG K per m^3, which is a more equitable distribution of timber resource rents across the value-chain (see Fig. 2).

5. Discussion

Our findings indicate that the existing forest polices/regulations are the cause of informal market activities. The current TA harvest permit does not meet the needs of the FROs, portable saw-millers, and manufacturing businesses because it does not match the size of harvests being conducted or the immediate monetary needs of the FROs. The volume of logs typically harvested with the portable sawmills is substantially smaller than the TA allotment of 5000 m^3. The existing ambiguous forest policies state that FROs can harvest up to 500 m^3 per annum without a harvest permit for non-commercial personal needs, implying that personal needs never require monetary transactions. We found that the FROs sell their timber to access cash to pay for immediate needs that occur throughout the year. This is collaborated by a technical report on the legality of small-holder timber production in PNG, which indicates that FROs view their forests as automatic teller machines (ATMs) and make withdraws (sell timber) when they have immediate financial needs such as school fees (Jenkins, 2016). We determined that informal market timber sales are indeed commercial activities conducted to fund the personal needs of FROs that can only be acquired through cash payments. In addition, the revenues that FROs would receive from a timber harvest using a TA permit would be much larger than their immediate cash needs. For example, if 5000 m^3 were harvested and the average payment per m^3 of log was 15 Kina, the total payment would be 75,000 Kina. Only 15% of the population in PNG has a bank account (Bakani, 2018). In the absence of a bank account, the majority of FROs do not have a safe place to store their cash. Furthermore, the FROs would have to wait for the forest to regrow before they could conduct another harvest for their immediate cash needs.

The TA regulations and application system are onerous for SMFE participants resulting in the majority choosing to operate in the informal market. In particular, the requirement to pay a 20,000 Kina performance bond is beyond the financial means of the majority of SMFEs. In addition, the approval process to obtain a TA can take several months, which does not fit with the FROs planning timeframe; which is usually dictated by the immediate need for cash. Our analysis found that the combination of the performance bond and the time required to obtain a TA result in the majority of SMFE participants operating in the informal market. A similar finding has been found in a study on transaction cost economics of community forest enterprises (CFEs) in

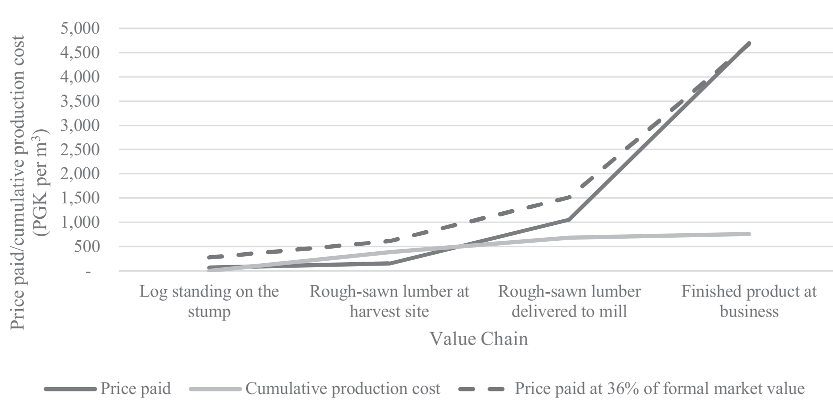

Fig. 2. Comparison of price paid and cumulative production cost of *Intsia bijuga* T&G flooring at different stages of the value-chain (PGK per m^3).
Note: Cumulative production cost does not include price paid for the timber products.
The PGK to USD exchange rate is 0.2970.

Quintana Roo, Mexico. In that study, it was found that governance processes can act as a type of transaction cost on CFEs, which can result in the CFEs divesting from the government coordination processes to improve profitability (Vega and Kenan, 2016). While the people are the owners of the forest land in PNG, the current forestry legislation has severely limited their access to the commercial rights of their land. The compromise of constitutional community forestry rights due to governance that favours industrial-scale multinational logging companies has been recognized in other PNG case studies (Ojha et al., 2016). Similar experiences government regulations community commercial rights to their timber have been identified in other tropical countries; e.g. Mozambique (Macqueen et al., 2012).

The current informal market distribution of resource rents is skewed to the latter stages of the value-chain, resulting in an inequitable share of timber resource rents to FROs. The timber resource rents of 9% received by FROs is slightly better than the rents being paid to FROs through fixed-rate royalties by industrial-scale logging companies, which averaged 5% of the formal export market value in 2017 (Scudder et al., 2019a). However, our analysis indicates that this is not an equitable distribution of the timber resources rents, with the bulk of the timber value having been captured by the small-scale manufacturing businesses. Based on our interviews of the informal market participants, we surmised that the informal market rough-sawn lumber prices paid to FROs are based on the existing formal market fixed-rate timber royalties set by the government. If the formal market fixed-rate royalties are not increased it is unlikely that the informal market prices paid to FROs will increase much above the current rates. We found that there are a limited number of small-scale manufacturers that have control over market knowledge, which allows them to negotiate opportunistic timber purchasing prices. This finding is similar to that of Vega and Keenan (2014) who found that the major sources of transaction costs on firms and community forest enterprises in Mexico arose from opportunistic behaviour of external timber buyers that had control over harvesting equipment resources and control over market information. Transaction costs arising from a monopoly on market knowledge was also identified by Pulhin and Ramiez (2016), who found that timber buyers have the upper hand in price negotiations with small-scale timber sellers in the Philippines, which they determined tends to depress the prices of timber in informal markets.

The vague government policy discussing the definition of 'commercial activities' for timber harvests less than 500 m^3 per annum creates a question of informal market participant legality, which is an impediment to the economic development of the small-scale forest products market in PNG. Most of the sawmill owners are unable to finance the purchase of machining equipment and therefore are not able to realize the gains in profitability being captured by the small-scale manufacturing businesses. Our findings suggest that the size of the informal market could be equivalent to 17% of current round wood exports, which highlights the unmet economic potential occurring in the small-scale forestry sector. If more saw millers could incorporate further processing of the rough-sawn lumber, the competition within the small-scale manufacturing businesses would increase. In the absence of increased competition, it is unlikely that the true value of the FRO's timber will be recognized, allowing FROs to receive larger per unit payments for their timber. In addition, since most of the sales transactions have been out of view of the PNG government, values normally paid to the government in the form of taxes has not occurred.

During data collection interviews in May 2018, we were made aware that the PNG government is planning to ban all log exports by year 2020. This was corroborated by non-participant stakeholders and a recent newspaper article, which describes the reason for the ban being to promote increased processing and jobs within the country (National, 2018). Approximately 90% of all logs harvested legally in PNG are exported (PNGFA, 2009), with logs exports in 2017 estimated to be 3.1 million m^3 (SGS, 2018). If the government follows through with the log ban, then either future log harvests will dramatically decline from present levels, or there will need to be a substantial increase in domestic processing businesses. A review of the PNG Forest Industries Association (PNGFIA) membership listing and the PNG business directory, indicates that there are 28 fixed-site sawmills in PNG, one plywood manufacturer, and eight furniture manufacturers (PNGFIA, 2009; PNGDL, 2015). Data collected from (ITTO, 2018), indicates that in 2016, PNG manufacturers produced approximately 82,000 m^3 of sawn wood, 29,000 m^3 of plywood, and 62,800 m^3 of veneer. This indicates that if the log export ban occurs, the existing domestic processers will not have the operational capacity to process the log volumes that were historically destined for export. Two of the small-scale manufacturing businesses that we spoke with believed that the log export ban would be good for their businesses and had begun to position themselves for increased production. However, FROs will likely face increased competition and reductions in prices received if a glut in logs overwhelms the formal and informal markets. A further reduction in timber resource rents to FROs would further exacerbate the already skewed rent distributions.

Our results suggest a need for revising the existing small-scale timber harvest permits and increased governmental assistance provided to small-scale wood product processors. We estimated that 90% of the informal market operators harvest less than 500 m^3 annually and the remaining 10% of operators harvest between 500 m^3 and 1000 m^3 annually. However, these harvests occur at multiple sites and are unlikely to ever exceed 500 m^3 per site. Therefore, we recommend that forest policies be revised to include a new small-scale harvest permit of 500 m^3 per site per annum. We also recommend that the performance bond requirements be adjusted to 2000 Kina to reflect the change in harvest volume. This change in the performance bond amount maintains the ratio of required Kina per m^3 harvested in the existing TA harvest permit performance bond. Furthermore, recommend that the formal market timber royalty payments to FROs be revised to reflect a fair distribution of timber resource rents. We suggest that timber royalties be revised for all existing timber harvest permits and applied to our recommended small-scale timber harvest permit (see Scudder et al., 2019a).

Our research has also revealed that there is a need for additional support, such as forest management plans, harvest plans, disbursement of market data (prices, lumber species and dimensions), sawmill training, training for further processing, and channels to access financing. This type of assistance is typically provided by extension foresters. We recommend that the PNGFA develop appropriate policies and regulations for implementing improved extension services for small-scale forestry participants. In addition, appropriate tax mechanisms and small-scale harvest permit default penalties could be included in revised regulations. One opportunity for increasing channels to access financing is the exploration of using standing timber as collateral for receiving bank loans to acquire milling and machining equipment. Funding for extension forestry could be provided by fees or levies linked to a new small-scale harvest permit. Towards the end of our data collection, we began to ask FROs and portable sawmill operators their viewpoint on paying a fee/levy for a small-scale harvest permit that would legalize their operations and take them out of the informal market. Their responses indicated that they would be willing to pay a fee, if it resulted in additional government support that would improve their productivity and profitability.

An additional alternative for improving the returns on timber harvests to FROs that has been the subject of research by the PNGFA and the Australian Centre for International Agriculture Research (ACIAR), is the establishment of a Central Processing Unit (CPU). The proposed CPU would essentially function like the small-scale manufactures discussed in this paper, but with an institutional framework that would share ownership with the FROs and/or the PNGFA. At the time of this writing, the optimal institutional framework and operating model has yet to be identified.

6. Conclusion

The existing small-scale timber harvest permit regulations provided disincentives for the FROs, and saw millers, and small-scale manufacturing businesses to operate within the law and to contribute substantially to the formal PNG economy. FROs chose to participate in the informal small-scale forestry market to acquire money for immediate financial needs that did not match the time-line of the TA process. The size and duration of the harvests conducted by portable saw-millers was typically dictated by the economic situation of the FROs rather than the TA harvest permit regulations. Our findings reinforce multiple analyses in which the authors recognized that enabling forest polices and regulation are crucial for the success of community-based/small-scale forestry (Macqueen, 2012; Macqueen et al., 2012; Baynes et al., 2015; Gilmour, 2016; Hoare, 2016, and Ojha et al., 2016). We recommend that forest policies be revised to include a new small-scale harvest permit (500 m^3 per site per annum), along with improved timber royalty rates for FROs. We also recommend that additional assistance be provided by the government extension foresters to aid in the sustainable development of small-scale wood product processing businesses. Our methods used in this analysis provide a framework that can be replicated in other countries to aid in identifying specific forest policies that are causing informal market activities and limiting the economic potential of small-scale forestry.

Declaration of Competing Interest

None.

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Research Project Brief
Policy Options

Papua New Guinea's Small-Scale Timber Market

Creating an enabling regulatory framework and improving financial returns to forest resource owners

ACIAR

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PNGFA

USC AUSTRALIA

FOREST RESEARCH INSTITUTE Papua New Guinea

Executive Summary

This research project brief summarizes regulatory constraints that may be hindering rural forest resource owners (FROs) from accessing formal timber markets and realizing a fair financial return from timber harvested on their lands. These FROs rely on their forests for providing a portion of their income. A review undertaken by the Australian Centre for International Agricultural Research (ACIAR) has identified the following regulatory constraints:

1) The 1991 Forestry Act does not clearly define regulations for timber harvests by landowners that are less than 500 m^3. The predominant view is that harvesting for personal use is acceptable, but commercial use is a violation of the regulations.

2) The Timber Authority small-scale harvest authorisation is an inappropriate fit for most smallholders because they harvest less than 500 m^3 per annum and they do not have the financial resources to provide the required performance bond.

3) The real value of the formal market timber royalties paid to FROs have been eroded by inflation, with an average decline in real value of 53% since 1991.

4) An effect of the above three constraints has been large-scale participation in the informal timber market, which operates outside the government's regulations.

Policy options for creating an enabling regulatory framework:

This policy brief has identified policy options that can help address these constraints to create an enabling regulatory framework that can aid in improving the livelihoods of these rural forest landowners:

- **Amend the Forest Policy Act to allow landowners to conduct small-scale commercial and/or personal timber harvests up to 500 m^3 per annum.**
- **Introduce a portable sawmill registration system and incentivise registration by having extension foresters advertise registered sawmillers to FROs.**
- **Increase extension forestry to assist landowners with management planning.**
- **Introduce a decentralized, bond-free, minimum fee, small-scale (500 m^3 per annum or less), timber harvest registration system for FROs.**
- **Continue to monitor, review, and adjust royalties in the future to reflect changes in the real market value of timber.**

Introduction

From 2017 to 2020, ACIAR undertook a review of small-scale timber harvest operations in Papua New Guinea (PNG), and the financial returns received by FROs for timber harvested on their lands. The purpose of the review was to identify constraints that may be hindering rural FROs from accessing formal timber markets and to identify potential options for improving financial returns to FROs.

The review identified that there are two timber markets in PNG. The first market is the formal market and is characterised by industrial timber harvests being primarily conducted by foreign logging companies through timber concessions received from the PNG government. The second market is an informal market that is predominantly comprised of small-scale participants operating portable sawmills. In both markets, the FROs receive a relatively small portion of the market value of the timber harvested on their lands.

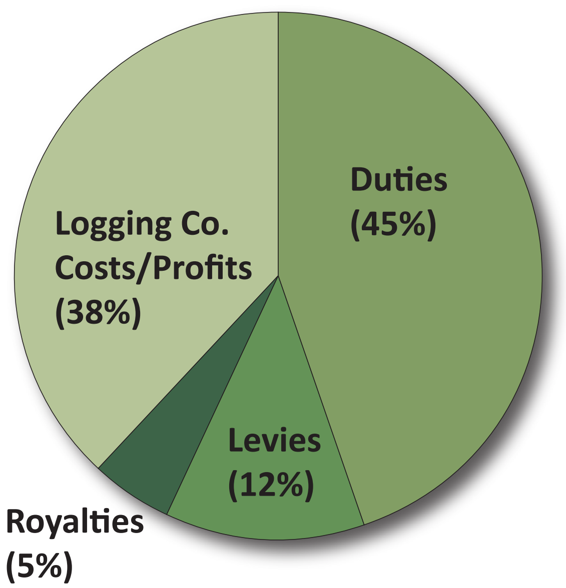
The review identified several constraints in the existing forest regulations that prevent small-scale forestry participants from accessing formal timber markets. In addition, it was found that these constraints have inadvertently provided incentives for participating in the informal market, which operates outside the Forestry Act and supporting legislation, and purview of the PNG Forest Authority. This policy brief draws on the review to summarize why these constraints incentivise informal market participation, as well as offering policy actions that may improve the status quo.

1. The formal timber market

In PNG, approximately 97% of the forest lands are held under customary land ownership by rural clan groupings. The typical process for an industrial-scale timber harvest involves the PNG Forest Authority entering into an agreement with customary landowners for access to their timber rights. These rights are then assigned to a registered forest industry participant as a timber concession. During the last decade, annual timber harvest volumes in the formal market have averaged 3.4 million cubic meters (m^3). Approximately 90% of the timber harvested is exported. The logging companies are required to pay timber royalties to the customary landowners. These royalty rates have minimum fixed values that vary by species. The fixed rates were initially set in 1991 at 10 PGK per m^3 for all species. In 2008, the Forest Minister increased the rates for select species in the Group 1 category. The royalty rates for species in Groups 2, 3, and 4 have not changed since 1991.

The logging companies are also required to pay duties to the PNG government for all logs exported. In addition, the PNG government collects timber harvest levies. These levies vary by each Forest Management Agreement and are typically used for economic development activities. This review found that the royalties currently received by FROs represented approximately 5% of the timber market value.

Distribution of market value



Timber royalty rates per m^3

Group/Species	PGK
Intsia bijuga	35.00
Palaquium spp.	20.00
Dracontomelon dao	20.00
Remaining Group 1 species	15.00
Groups 2,3, & 4 species	10.00

2. Erosion of the value of timber royalties

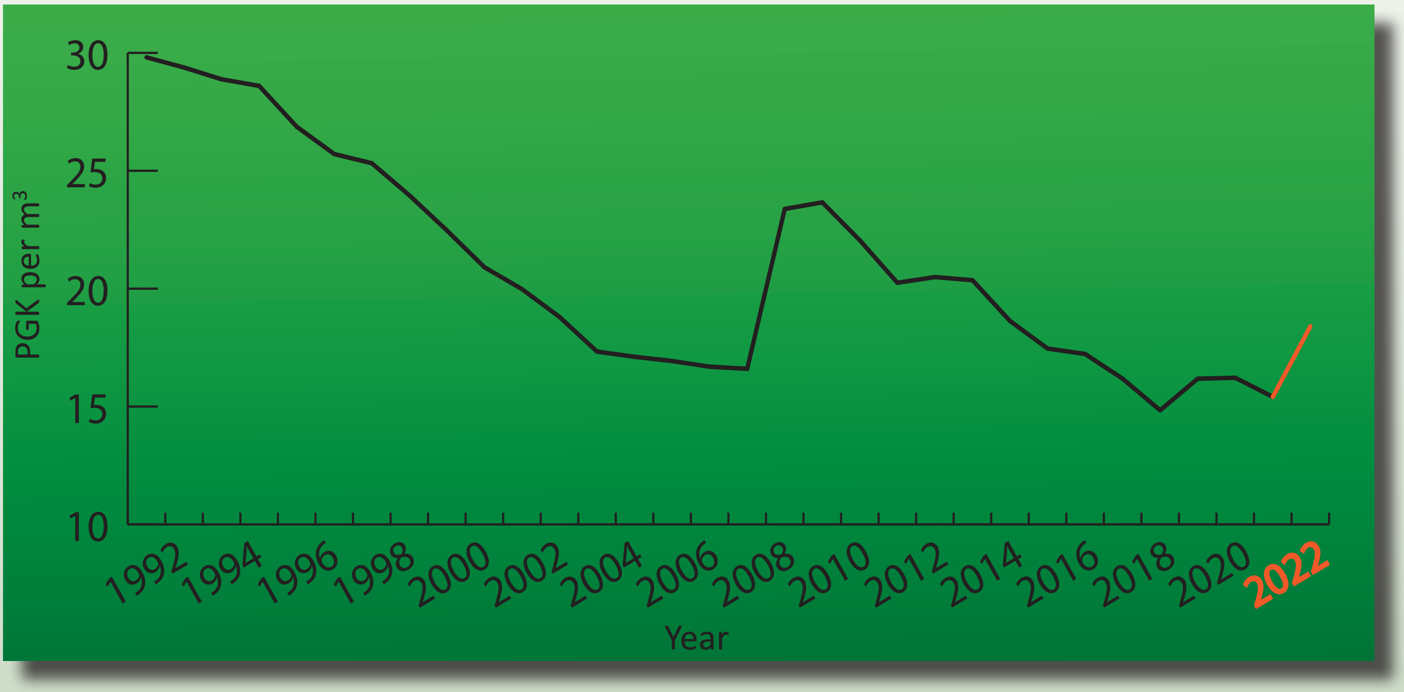
PNG has experienced an average annual inflation rate of 7% since 1991. Since the timber royalties are fixed rates by species, the weighted average real value of all the timber royalties has declined by 53% from 1991 to 2020. The real value of royalties for Groups 2, 3, and 4 species have declined by 70% from 1991 to 2000, since the rates for these species have never been increased despite representing an average of 35% of timber harvest volumes.

By comparison, the log export duties collected by the PNG government are calculated with a progressive tariff rate based on the Free on Board (FOB) market value of the logs. This protects the tariff rate from the erosion of real values caused by inflation.

The result of the fixed-rate royalty is that the real value of the financial returns that FROs receive from timber harvests on their lands is getting smaller every year. An unintended consequence of the low royalties paid to the FROs has been the creation of an informal market of small-scale timber harvesting in the country's native forests.

In late December 2021, Circular Instruction No. 25/2021 by the PNG Forest Authority was issued as a public notice for the timber royalties to be increased by 20%, effective as of 1st January 2022. If the timber harvest volumes by species in 2022 is representative of the average for the last decade, the average real value of timber royalties will increase to approximately 18.40 PGK per m^3.

Average real value of timber royalties per m^3 (2021 PGK)



3. Summary of eco-forestry in PNG

Beginning in the 1990s, several organizations attempted to facilitate small-scale native forest management by FROs. These organizations utilized an 'eco-forestry' approach, involving selective harvesting of timber combined with the milling of timber by Indigenous forest landowners using portable sawmills. The lumber produced was aggregated at various Central Marketing Units (CMUs) to be collectively sold into local and international markets as sustainable certified lumber under Forest Stewardship Council (FSC) principles. The use of portable sawmills was also intended to provide the landowners with a greater financial return compared to the timber royalty payments they could receive from logging companies in the formal market.

It was found that this approach to small-scale forestry was not financially viable in the long run despite massive subsidization by the eco-forestry organizations. The FROs did not possess the required milling and business capacities for meeting the quantity and quality production targets necessary for financial viability. The eco-forestry organisations attempted to meet quantity targets by increasing the number of portable sawmill operations. This ultimately over-extended the ecoforestry organization's ability to provide adequate facilitation services to the portable mill operators.

This review determined that increasing the number portable sawmills is not an efficient approach for increasing economies of scale, because modern industrial-scale sawmills are able to produce the same products at lower costs.

All the eco-forestry sawmilling operations have ceased and most of the ecoforestry organizations have disbanded. Those that remain have changed their operational focus towards different activities.

While eco-forestry sawmilling activities are no longer occurring, the use of portable sawmills by FROs is still prevalent. Most of the portable sawmill use is occurring within the informal market.

4. Financial viability of portable sawmills

To investigate the profitability of portable sawmills operated by small-scale forest enterprises, a discounted cash flow model with a Monte Carlo risk analysis simulation was developed.

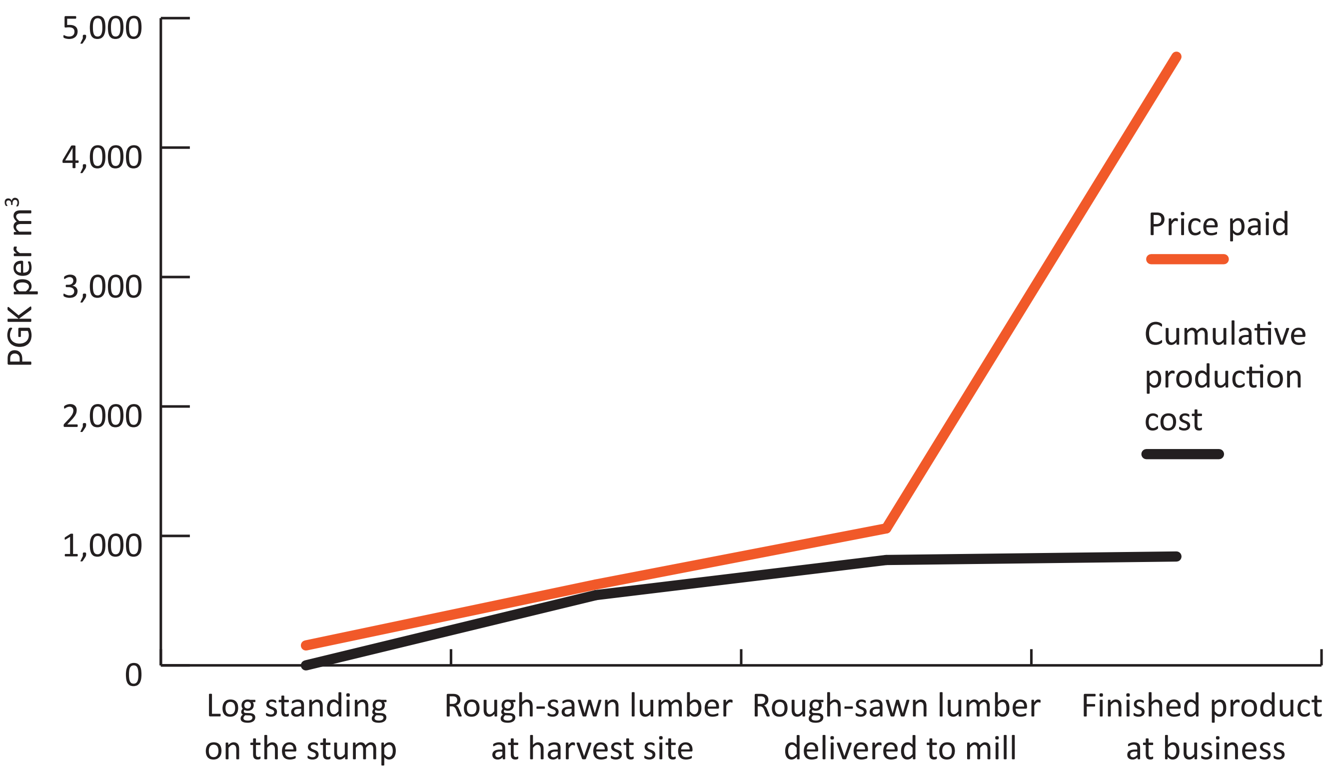
It was found that the application of this small-scale native forest management model has a high likelihood of producing a negative net present value (NPV). The cash outflows to produce the lumber were found to be consistently greater than the cash inflows from lumber sales.

On average, only 4% of the simulations achieved a positive NPV. When only the most valuable species were harvested (*Dracontomelon dao, Intsia bijuga, Pometia pinnata,* and *Pterocarpus indicus*), an average of 56% of the simulations received a positive NPV. However, the FROs would be at risk of overexploiting or high grading the most valuable timber species. This analysis highlights the importance of adding further value to the wood products beyond rough-sawn lumber.

5. The informal market

The informal market can be separated into three participant groups; 1) FROs, 2) portable saw-millers, and 3) small-scale wood product manufacturing businesses. Some FROs own their own portable sawmills and harvest and mill timber on their own lands, while others sell their timber to portable sawmill owners. The saw-millers sell the rough-sawn lumber to the small-scale manufacturers that further process the rough-sawn lumber. The most common wood products produced are dressed structural lumber, tongue & groove flooring, decking, weatherboard, and mouldings. Most of the small-scale manufacturers also own their own portable sawmills and source timber directly from the FROs as well. The review found that the FROs typically receive between 20 and 77 PGK per m^3 of timber, with *Intsia bijuga* providing the highest price. The informal market price for *Intsia bijuga* is more than double the price received in the formal market. However, most of the timber value is captured by the small-scale manufacturers. The average price received by the manufacturers for *Intsia bijuga* tongue & groove flooring was 4,702 PGK per m^3, which was 522% larger than the cumulative variable production costs.

Comparison of prices received and cumulative production costs for *Intsia bijuga* T&G flooring (PGK per m^3)



6. Exploration of Central Processing Units

An alternative model that has been proposed for small-scale native forest management is the use of a Central Processing Unit (CPU). This model was suggested to overcome the lumber milling quality challenges that was experienced in the eco-forestry operations. The operational concept of CPUs was that rejected export logs could be collected and transported to CPUs for processing. The CPUs were to be strategically located at centralized points to achieve economies of scale related to log transportation. In addition, the CPUs would also purchase rough-sawn lumber from portable sawmills and timber from FROs. It was proposed that the CPUs could be managed by a government agency or by an established wood processing entity. An additional recommendation was to establish a board of representatives that ensured that transparent market information was disseminated and that fair prices were established. During a previous ACIAR project, several CPU operational models were circulated to various wood processing companies for comments and recommendations.

At this time, there have not been any CPUs established based on these operational models. However, there are small-scale wood product manufacturing businesses operating in the informal market that utilize similar operational models. These businesses have been able to overcome the lumber quality issues experienced by the eco-forestry operations and have been able to maintain their operations without financial subsidization.

There are two issues of concern with these businesses; 1) some of the businesses operate outside of the PNGFA timber harvesting regulations (TA); and 2) many these businesses have a monopoly on market price information, allowing them to control the prices that FROs and portable sawmillers receive for their timber.

7. Defining the Timber Authority

The Timber Authority (TA) is the small-scale forest harvest authorisation in PNG. There are five specific arrangements of the TA. This policy brief is focused on the TA for domestic processing (TA-01). A TA for domestic processing allows a registered 'forest industry participant' (FIP) to harvest up to and not exceeding 5,000 m^3 over the duration of one year, through selectively harvesting from the natural forest for downstream processing. Forest Regulation Form 210, defines an FIP, as any person engaging in, or intending to engage in forest industry activities where the timber harvested, processed, bought, sold, arranged or procured to be sold or purchased, by that person in a calendar year exceeds 500 m^3 in volume.

The 1991 Forestry Act does not clearly define regulations for timber harvests less than 500 m^3. The Act implies that individuals can harvest up to 500 m^3 per annum for personal use, but not for commercial purposes. The Forestry Act does not define what qualifies as commercial use versus personal use. This vagueness in the wording has resulted in different interpretations of what the intent is for harvests less than 500 m^3. The predominant view is that personal use refers to harvesting timber for constructing personal homes, other personal buildings, and for fuel wood. Commercial use refers to the exchange of timber for money and/or other goods, which is predominantly viewed as a violation of the regulations.

The TA application process:

The process requirements for receiving a TA begin with an individual becoming a registered FIP. This requires the creation of a legal business entity, a completed registration form delivered to the Managing Director of the PNGFA, and a 275 PGK application fee for PNG nationals. The TA application process requires among other things; a 275 PGK application fee for PNG nationals, the estimated harvestable volume, plan of the timber utilization, map and description of the proposed forest area, a verification of ownership and consent form, and a sales and purchase agreement signed by the forest resource owners and witnessed by a village court magistrate or land mediator. When a TA is approved, the submission of a performance bond is required that is only released after the submission of a harvest completion report and verification that all terms and conditions of the TA are met.

8. Forest resource owners sell their timber for immediate monetary needs

FROs view their forests as a bank automatic teller machine (ATM) and make a withdrawal (small-scale harvest) periodically for immediate monetary needs:

- **School fees: All expenses related to school, any actual school fees, project fees, stationary, uniforms, and transportation to school.**
- **Store-bought goods: Consumables that FROs cannot provide for themselves such as clothing, packaged rice, and canned meat.**
- **Ceremonies, such as weddings and funerals.**
- **Home construction: Lumber materials and non-lumber materials; nails; plywood; metal siding; roofing materials; doors; windows; and window screens.**
- **Christmas celebrations.**

9. Reason's participants do not use a TA

- **Most portable saw-millers harvest less than 225 m^3 per year.**
- **The maximum annual operational capacity of most small-scale timber producers using a portable sawmill is typically less than 500 m^3.**
- **The TA is for timber harvests between 500 m^3 to 5,000 m^3 per year.**
- **Most participants are not aware of the TA application processing procedures.**
- **Most participants are not able to provide the required performance bond.**
- **TA applications can take several months to process.**
- **FROs sell their timber for immediate monetary needs.**

10. Uncertainty: Increased log export taxes

Much uncertainty currently exists within PNG's forest products industry. In 2020, the PNG government increased the log export tax in its 2020 Appropriation Bill. Suggested reasons for the increased log export tax were; 1) to stimulate increased downstream wood product processing; 2) to recover log export revenue leakages; 3) to fund increased royalty payments to forest resource owners; and 4) to introduce a legal mechanism for reducing log exports.

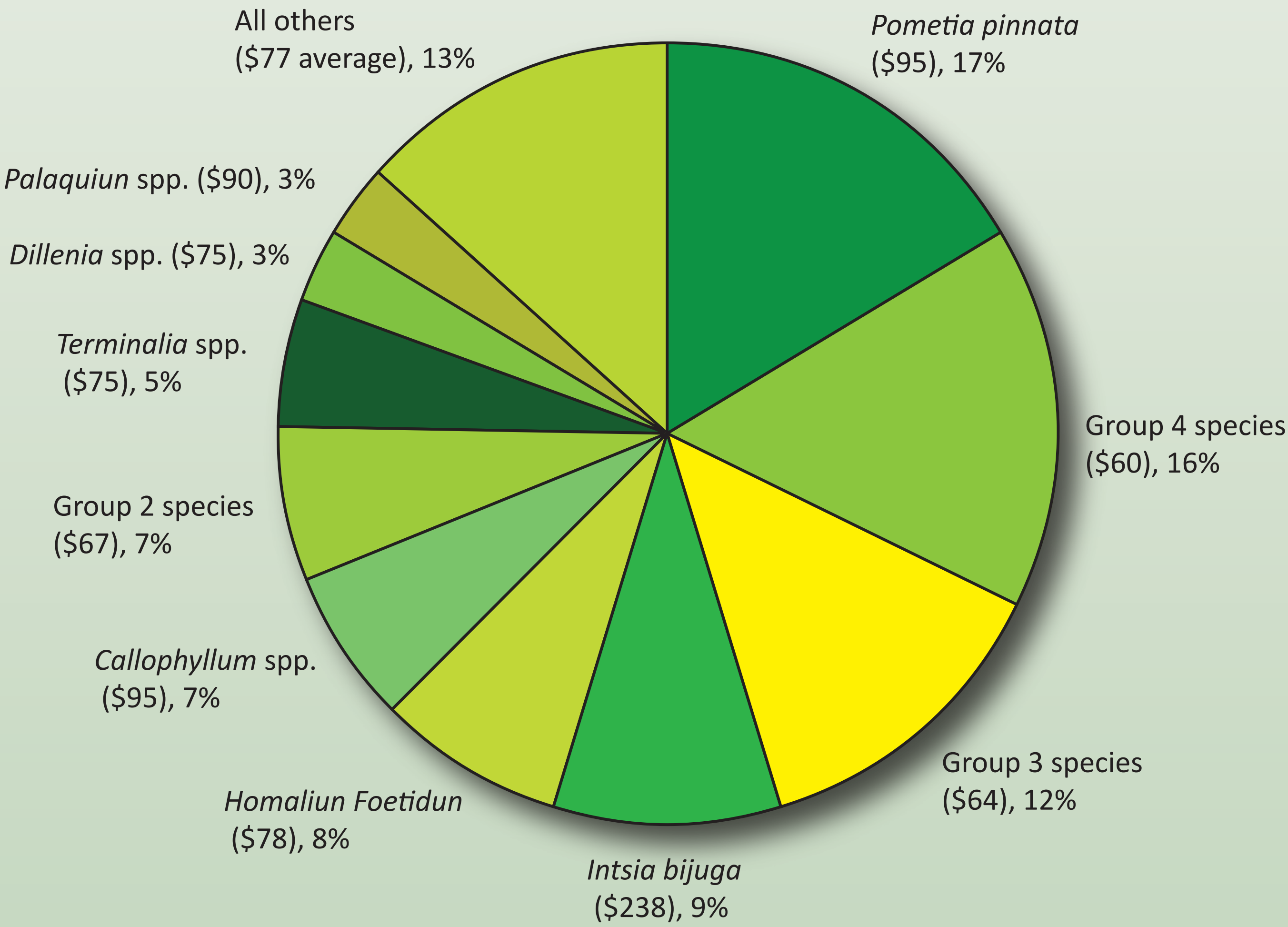
In 2019, the weighted average tax percentage rate for PNG log exports was approximately 34%, with an average tax price of $35 per m^3 (USD). In 2020, the weighted average tax percentage rate increased to approximately 45%, with an average tax price of $44 per m^3 (USD). Meanwhile, the average royalty payments paid to landowners for timber harvested on their lands is still about $5 per m^3 (USD).

The long-term impacts of the increased log export taxes to the industry are unknown. In 2020, log export volumes declined by approximately 23% from the previous year. In addition, it is unknown how these changes in the industrial sector will influence small-scale timber harvest operations and small-scale wood product manufacturers. The future is uncertain.

Comparison of log export tax calculations by value per m³

Log value (USD/m³)	2019 tax rate	2020 tax rate
0 - 60	(Value * 25.00%)	(Value * 25.00%)
61 - 100	(Value * 35.83%) - 3.56	(Value * 48.93%) - 3.56
101 - 150	(Value * 36.65%) - 4.76	(Value * 55.85%) - 4.76
151 - 200	(Value * 43.05%) - 12.26	(Value * 57.91%) - 12.36
200+	(Value * 48.05%) - 18.26	(Value * 58.84%) - 16.36

Average 2020 price per m³ (USD), and average annual percent of volume exported by species (2011-2020)



11. Summary of the challenges and constraints

- The value of the timber royalties being received by FROs in the formal market have been eroded by inflation, thus inadvertently encouraging participation in the informal market where higher prices and more immediate transactions can be received.

- The TA harvest authorisation was primarily designed for legal logging business entities and was not designed to meet the needs of FROs. FROs generally conduct timber harvests to meet immediate and often urgent cash requirements, resulting in small and irregular harvest volumes. Because of this, FROs typically do not bother applying for a TA.

- Informal market participants are operating outside the Forestry Act and supporting legislation, and the purview of the PNG Forest Authority. As such, there is no monitoring on harvesting removals, which poses a threat to sustainable timber harvesting practices.

- At the prices currently being received for rough-sawn lumber, portable sawmilling is financially viable only when the most valuable timber species make up the bulk of the harvest. Therefore, it is probable that the high grading of these valuable tree species is likely to occur in forest areas accessible to portable sawmillers.

- The majority of portable sawmillers in the informal market have received minimal training. Thus, the rough-sawn lumber produced is generally of low quality and does not adhere to any lumber grading standards or codes. Hence, this lumber is less valuable in the domestic market and largely falls below international market standards.

- FROs and portable saw millers are generally uninformed of the true value of their timber products throughout the value chain, relative to the small-scale wood product manufacturers operating in the informal market. Consequently, it is likely that they are not realizing the full economic potential of their timber and the benefits it can provide to their families and communities.

12. Policy options to improve the situation

- **Amend the Forestry Act to allow FROs to conduct small-scale commercial and/or personal timber harvests up to 500 m^3 per annum:** Amend existing regulations to allow FROs to harvest up to 500 m^3 for commercial purposes from a given site per annum, subject to the approval of PNGFA local extension foresters. To mitigate the potential for abuse of this amendment, such as the incidents that occurred under the terms of the 1971 Forestry Private Dealings Act (repealed in 1992), require that all commercial timber harvests be performed by portable sawmills and operators that have been registered with the PNGFA.

- **Introduce a portable sawmill registration system:** Develop a system for registering portable sawmills and mill operators with the PNGFA. Make registration provisional on the completion of a portable sawmill training course to improve the quality of lumber production and adherence to sustainable timber harvesting practices. As an incentive for registration, have extension foresters advertise the services of registered portable sawmill operators to FROs for pursuing small-scale commercial harvests.

- **Increase extension forestry:** Provide resources, logistical support, and financing for increasing the number of PNGFA extension foresters for the purposes of; assisting FROs in developing forest management plans and timber harvest plans; educating FROs on market prices; linking FROs with registered portable saw millers; registering their timber harvests; ensuring that harvest agreements are upheld and harvesting regulations are followed; providing tree seedlings for reforestation, and providing forestry-based training and education.

- **Introduce a decentralized, small-scale, timber harvest registration system:** Develop a decentralized, bond-free, minimal fee system, for registering commercial timber harvests up to 500 m^3 per annum, between FROs and registered portable sawmill operators with PNGFA local extension foresters.

- **Continue to monitor, review, and adjust royalties in the future:** Adjusting timber royalties will aid in the reduction of real royalty values caused by inflation, and likely increase the timber values received by FROs in the small-scale market.

ACIAR Project FST/2016/153 undertook a review of Papua New Guinea's small-scale timber market. The objective of the review was to identify regulatory constraints that may be hindering rural forest resource owners from accessing formal timber markets, and to identify potential options for improving financial returns to smallholders that have timber harvested from their lands.

This research project brief draws on that review to summarize the constraints related to the existing small-scale forest harvest regulations and why they incentivise informal market participation. The project brief offers policy actions that may improve the status quo.

The research project brief is targeted at Papua New Guinea policymakers, practitioners, researchers, communities, and civil society.

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ACIAR

Papua New Guinea Small-scale Reduced Impact Logging Code of Practice

Prepared for activity 3.3 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By,
Micah Scudder, Charles Tsiritsi, and Grahame Applegate
June 2020

The following 12 logging codes of practice have been developed for small-scale timber harvests in Papua New Guinea. The purpose of the 12 codes is to reduce potential negative impacts on the environment from timber harvests, improve logging operator safety, and to improve the efficiency of the timber harvests.

1. **Minimum cutting diameter of harvest trees**: 50 cm DBH

2. **No trees should be harvested within designated buffer zones**. These buffer zones are for cultural areas, lakes/lagoons/shoreline/water storage area, and watercourses. The buffer zones should be clearly marked with flagging. The colour of the flagging should be different than the colours selected for tree marking.
   - Cultural areas = buffer of 30 m.
   - Lakes/lagoons/shoreline/water storage areas;
     - Slope < 17% = buffer of 50 m.
     - Slope > 17% = buffer of 100 m.
   - Watercourse:
     - Class 1 stream (Width of stream base > 20 m) = buffer of 30 m on each side.
     - Class 2 stream (Width of stream base is 10 – 20 m) = buffer of 20 m on each side.
     - Class 3 stream (Width of stream base < 10 m) = buffer of 10 m on each side.

3. **Tree marking**: Trees to be harvested are marked with paint and include a selected symbol for the appropriate felling direction. The felling direction should be determined by identifying the direction that will best avoid damage to other trees. If possible, trees to be harvested nearby should be felled into the same gap. The stump height that the tree is to be cut at should also be marked. Stump heights should be minimized to capture a greater volume of timber. Leave trees that are near the trees to be harvested should be marked with a different colour of paint or a different colour of flagging.

4. **Timber harvest gap sizes**: Should be limited to 2-3 trees.

5. **Vine and liana cutting**: All vines and lianas existing on trees to be harvested should be cut 3-6 months prior to the harvest. This should occur at the same time the trees are marked.

6. **Timber harvest sketch map**: Should be prepared to clearly identify the harvest area, harvest trees, buffer zones, and ingress/egress areas for accessing the site. This sketch map is for the benefit of the harvesting/milling business to aid in their planning.

7. **Landowners notice of harvest activities**: Landowners should be given notice of the expected dates that the timber harvest is to occur prior to implementation.

8. **Personal protective equipment (PPE)**: All personnel participating in the harvest and milling operations should wear appropriate PPE: Safety helmets, ear protection, eye protection, high-visibility vest, long pants, chaps if operating a chainsaw, and boots.

9. **Fuel/oil storage**: All fuel, oil, and other chainsaw/portable mill fluids should be kept in securely closed containers. Care must be taken to prevent spillage during re-fuelling.

10. **Refuse disposal**: All refuse should be removed from the site once the operations have been completed. The refuse should be deposited at the appropriate dump or recycling site.

11. **Cost analysis**: Forestry extension workers should work with the harvesting/milling business to assess operational costs of each harvest to improve future harvest plan estimates.

12. **Post-harvest assessment**: Forestry extension personnel should conduct a post-harvest assessment to determine if the logging code of practice has been followed and that payments have been made to the landowner for timber harvested. If parts of the harvest operation need improvement, this should be conveyed to the harvesting/milling business and addressed in any future small-scale RIL training.

Small-scale Forest Management Plans and RIL Demonstration

Final Report prepared for activity 3.4 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder & Grahame Applegate
July 2022

1 Introduction:

This report responds to project activity 3.4 'Undertake demonstration of RIL and management plans for clans.' This activity was intended to occur in Oomsis, within the Morobe Province. The operational activities that were planned include developing a small-scale forest management plan with the landowners, conducting a forest inventory of the specified site, preparing the site for a timber harvest utilizing RIL activities developed in activity 3.3, and conducting a harvest and milling demonstration with a portable sawmill. The expected participants included staff and students from TFTC, staff and students from the Forestry College at UniTech, and staff from PNG FRI. The landowners that were selected for this activity have an ongoing working relationship with TFTC. TFTC had arranged a timber authority to harvest timber on their lands, and the landowners had agreed to letting us conduct the demonstration.

Unfortunately, all project travel to PNG ceased in early 2020 due to the Covid-19 pandemic. We had hoped that this activity could be re-scheduled in 2021, and then again in 2022. Travel safety issues related to low vaccination rates in PNG have been the primary concern that has prevented this activity from occurring.

As an alternative solution, we proposed to conduct an online workshop via zoom, to provide training in small-scale forest management planning and timber harvest with RIL techniques. This activity is planned to occur in September 2022. The following sections outline our methods for the revised activity.

2 Methods:

2.1 Workshop materials:

We developed five Microsoft Word Documents for the online workshop. These are: 'Small-scale Forest Management Plan Manual' (Appendix 4.a), 'Small-scale Forest Management Plan Template' (Appendix 41.b), 'Small-scale Timber Harvest Plan Template' (Appendix 41.d), 'Small-scale Logging Code of Practice' (Appendix 41.c), and 'Small-scale Timber Harvest Sales Contract Template' (Appendix 41.e).

2.2 Workshop activities:

The workshop incorporated Microsoft PowerPoint lectures and break-out group simulation exercises.

The topics of the PowerPoint were on developing a forest management plan with landowner forest families, assessment of forest inventory data, developing a timber harvest plan with landowner forest families, and preparing a timber sale contract.

The break-out group simulation exercises were based on the lessons learned in the lectures. The workshop attendees were divided into small groups of 4-8 people. Half of the group members will play the role of the landowners, and the other half will play the role of extension foresters. The attendees will be asked to work together to complete the three templates discussed in section 2.1. Additional data will be provided to the groups: management objectives of the landowners, forest inventories, and timber prices. After the break-out session concluded, the groups presented the plans that they developed.

3 Workshop dates:

Tuesday 13th September (10:00 AM – 12:00 AM)

- Developing small-scale Forest Management Plans (FMP)

Wednesday 14th September (10:00 AM – 12:00 AM)

- Introduction to Reduced Impact Logging (RIL) techniques.

Thursday 15th September (10:00 AM – 12:00 AM)

- Developing and setting up small-scale timber harvest plans.

Papua New Guinea
Smallholder Forest Management Manual

June 2020

By,
Micah Scudder, Charles Tsiritsi, and Grahame Applegate

1 Introduction

This manual has been produced as an output for a research projected conducted by the Australian Centre for International Agricultural Research; ACIAR Project FST/2016/153 -Enabling Community Forestry. The purpose of this manual is to provide guidelines to extension foresters in Papua New Guinea (PNG) in implementing small-scale forest management activities.

The manual has been organized into three sections. These are; 1) small-scale forest management plans; 2) the small-scale logging code of practice; 3) small-scale timber harvest plans; and 4) small-scale timber harvest sales contracts.

2 Small-scale forest management plans

The following recommendations have been made to guide extension foresters in the development of small-scale forest management plans. This process should typically begin with receiving notice of interest from the landowners It is recommend that the landowners be an individual or individual family unit to limit any potential land tenure conflicts. The next step is a visit with the landowner to hold a meeting.

2.1 Initial meeting with landowners

The purpose of the meeting would be to ascertain the landowner interests and perform a quick survey of the forest property. The 'Smallholder Forest Management Plan Template' (SFMPT) should be used for recording the information learned during the landowner meeting.

Item 1: The forest site name. This can be designated by the name of the family, a geographical feature of the site, a preference of the landowners, or a combination of all three.

Item 2: The landowner names This list should include all the landowners for a given SFMP. It is important to identify all the landowners from the beginning in order to avoid any management decision disputes later.

Item 3: Landowner contact information. This information provides how to contact the selected landowner that will primarily be interacting with extension foresters.

Item 4: Plan author names and contact information. This provides the names of the extension foresters that met with the landowners and how to contact them.

Item 5: General forest description. This information is collected from a quick survey of the forest area: The purpose of the survey is to get an estimate of the size of the land area, a description of the forest cover, the identification of existing roads and structures, the identification of water features, and the identification of any special sites. The landowners may already have selected an area of their forest that they would like the harvest to occur. The history of the property should also be discussed. Property history refers to previous timber harvests, fires, flooding, landslides, or any other events that have previously occurred. These past events may have an impact on the future management activities.

While conducting a quick survey of the forest area, a pilot survey of the forest stand basal area (BA) should be conducted. This process involves conducting a quick point-sample survey using a prism. A prism with a basal area factor (BAF) should be selected that allows for 6-12 'In-trees.' A BAF of 2-5 should be appropriate. A range of 4 to 7 plots should be conducted at different locations in the stand. At each plot, calculate the BA by multiplying the number of In-Trees by the BAF. When all the plots are completed, calculate the mean BA and the standard deviation for the pilot plots. This data will be used to determine the appropriate number of point-sample plots that should be used during the more in-depth forest inventory.

Item 6: Landowner management objectives. This information is collected to understand what the landowners want to gain from their forests. Discussion of the management objectives should be given an adequate amount of time during the meeting to understand what the landowner's short-term (present to 5 years), medium-term (5-10 years), and long-term (10 years - next generation of owners) objectives are for their forests. Part of this process is identifying the future forest condition desired by the landowners relative to how it currently is. Management objectives can contradict each other, so it is important to identify all the objectives so that a balanced plan can be developed. The meeting would also identify the non-timber related concerns of the landowner, such as current and future garden sites, sacred sites to protect, water features to protect, any reforestation interests, as well as any other objectives.

If one of the management objectives in money generation from timber harvests, it is important to understand the details of the monetary needs; amount of money sought and the time of year it is needed. These details will dictate the parameters of a timber harvest. It is also important to know if these monetary needs are likely to happen every year, or if this is a one-time harvest, since it will have an impact on the forest management plan.

2.2 Preliminary draft of the forest management plan

The extension foresters will use the information collected during the initial meeting with the landowners to devise a preliminary draft of the forest management plan. This is done with the information collected in SFMPT items 5 (Forest description), and 6 (Landowner management objectives). A list of forest management activities should be developed to meet the landowner management objectives. This process should be done by identifying the specific actions that would need to happen to get to the desired future forest conditions, from the conditions that the forest is currently in. The selected activities will require that the extension foresters have knowledge of the ecological processes present at the forest site and knowledge of appropriate silvicultural techniques. These activities should include an approximate month and year that they would be implemented in. Item 10 of the SFMPT is a forest management activities calendar, which is where these activities should be entered. It should be noted that the SFMPT is still in its preliminary draft, and these activities can be changed at any time. This step is just to aid the planning process.

If a timber harvest for commercial interests is one of the landowner objectives, it will be necessary to conduct market research on the current timber prices. Timber species identified in item 5 of the SFMPT should be inquired upon to learn that the expected prices per cubic meter (m) of timber are currently being paid. This market information will help identify the parameters of the timber harvest that will meet the landowner's needs.

A preliminary SFMP draft should be developed from the identified forest management activities and timber market research. This preliminary draft can be brief (a couple of paragraphs), and simply has the purpose of guiding conversation during the second visit with the landowner.

2.3 Second meeting with landowners and conducting a forest inventory

During this visit, the preliminary SFMP will be discussed. The landowners will be told of the identified forest management activities and of the estimated parameters of a timber harvest, if it is one of the landowner objectives. If the landowners find the preliminary plan to be acceptable, a more in-depth assessment of the forest can be completed.

This more in-depth forest assessment is done to refine the expected forest management activities. If applicable, the forest can be separated into individual forest stands that are distinct by forest structure and composition, or by geographic location. This is done in Item 7 of the SFMPT. The process for the in-depth forest assessment will be done with variable-radius or point-sample plots along a strip-line in the forest stand. The number of plots to be completed on the strip-line are determined from the pilot plots conducted during the quick survey (Mean BA and standard deviation of mean), the Student's T-value table, the selected confidence level, and the selected standard error limit. It is recommended that a confidence level of 95% and a standard error limit of 10% be selected. The formula for number of plots is:

$$Number\ of\ plots = \left(\frac{Coefficient\ of\ variation * Student's\ T - value}{Standard\ error\ limit}\right)^2$$

*Coefficient of variation = (Standard deviation/mean) * 100*
Student's T-value = Selected from Table 1 below using the number of pilot plots (degrees of freedom) and the selected confidence interval.
Standard error limit: Recommend 10%.

Table 1: Students T-value table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

It a pilot survey was not completed, a general rule to follow for number of plots is; 8 plots for a stand that is 0.5 – 2 ha, 12 plots for a stand that is 2 – 10 ha, and 16 plots for any stand greater than 10 ha. Measurements to be taken at each plot are related to the In-trees; species name, DBH, and merchantable tree height.

While the forest assessment is being conducted, a forest sketch map should also be created. This sketch map should show the different forest stands, the property boundaries, water features, sacred sites, buildings, roads, and any other important details. The sketch map is included as Item 8 in the SFMPT. In addition, photographs should also be taken of each of the forests stands (Item 9 of the SFMPT).

2.4 Forest management plan revision

The SFMP revision is completed by considering the new information collected during the more in-depth forest assessment. This information should allow the extension forester to refine the selected management activities and to incorporate any new comments or requests from the landowners.

2.5 Forest management plan agreement

The forest management agreement is Item 11 of the SFMPT. This is an agreement between the forest landowners the authors of the SFMP. The agreement is that the plan accurately describes the current conditions of the landowner's forest, their management objectives for their forest, and the selected management activities to achieve the specified management goals of the landowners. This agreement is a guide to aid the landowners in implementing future forest management plan activities. It is not a binding contract and can be revised at any time.

3 Timber harvest plans

This section provides guidelines for developing a small-scale timber harvest plan. A small-scale timber harvest plan (TFP) template has been developed to aid in the planning process. This template incorporates the same design features and some of the same sections as the small-scale forest management plan template.

Items 1, 2, and 3 of the TFP template include the name of the timber harvest, the contact information for the primary landowner, and contact information for the authors of the THP. The name of the timber harvest can be name of the geographic site of the harvest or a name preferred by the landowners. The landowner and plan authors contact information can be copied from the FMP template. Item 4 of the THP is the landowner's objective for the timber sale. This can be a monetary objective or a specific silvicultural treatment to alter the forest stand to a preferred future condition. Item 5 of the THP contains a description of the forest stand to be harvested. This information can be copied from Item 7 of the FMP.

Items 6 of the THP provides specific information for the proposed timber harvest. The template provides a drop-down menu for the type of harvest. The choices on the drop-down menu are; an area limit, a diameter limit, and single tree selection. An area harvest is selected when all the trees within a specified boundary are designated to be cut. A diameter limit is used when all the trees within a designated area that are above a certain diameter will be cut. If an area limit or diameter limit methods are selected, it is important to make sure the harvest boundaries are clearly marked. For a single tree selection method, specific trees are selected to be harvested and marked with paint. Item 6 also included the volume and number of trees to be removed during the harvest. These estimates are determined during the forest assessment, which occurred during the development of the FMP.

Item 7 of the FHP is for notes that describe how the timber harvest should be conducted. This includes the tree species and volumes that will be harvested, how these trees are marked, the designated landing sites for the portable saw mills, how the buffer zones and special sites are marked, how the property boundaries are marked, and the designated access points for the timber harvesters/buyers. It is important the design of the THP adhere to the PNG Small-scale Reduced Impact Logging Code of Practice. Item 8 of the THP provides a check list to ensure that the logging code of practice is adhered to. Item 9 of the THP is for a timber harvest sketch map. This sketch map can be developed using the FMP sketch map or be copied from the FMP if the scale is appropriate.

Item 10 of the THP provides a table for recording all the logs that are harvested. This table includes cells for recording the species, diameter, length, and volume of each log. This table should be completed after the timber harvest, but before the logs are milled or removed from the property. These recordings will be used to determine the amount of money owed by the timber buyer to the landowners. It is recommended that the extension foresters conduct these measurements and recordings to ensure a fair and unbiased monetary exchange between the landowners and the timber buyer.

Item 11 of the THP provides a table for recording timber harvest cost information. This table has columns for the operator names, their organization, their job title, their hours worked, and their hourly wage. It is recommended that information be collected for; extension forester hours conducted during the timber harvest set-up, logger hours during timber felling, extension forester hours during log volume measurements, and logger hours during portable saw milling. Collecting this information is important because it will allow extension foresters to better estimate the operational costs of small-scale timber harvests. From information collected in Items 10 and 11, it is possible to calculate the average harvest cost per cubic meter of timber harvest set-up, felling, volume measuring, and milling. In addition, it will allow extension foresters to identify how these costs change with different species compositions, stocking per ha, slope, etc.

Item 12 of the THP provides a section for before and after photos of the timber harvest. These photos should be taken to ensure that the THP and the small-scale logging code of practice guidelines were followed. The photos also provide an opportunity for identifying where improvements can be made for future timber harvests.

4 Timber harvest sales contracts

This section provides guidelines for developing a draft of a smallholder timber sale contract. A smallholder timber sale contract (STSC) template has been developed to aid in the contract design. This template incorporates the same design features and some of the same sections as the small-scale forest management plan and timber harvest plan templates.

Note: This document is solely for the purpose of an educational training exercise. It should not be used as an actual contract of sale. Legal council should be sought for all timber harvest transactions. None of the project partners for ACIAR Project FST/2016/153, bear responsibility for any use of this document beyond educational training purposes.

Item 1 and 2 of the STSC includes the forest site name, the timber harvest plan name, and the dates of the proposed harvests. Item 3 is the date that the STSC is made and includes the names of all the landowners. Item 3 also includes the name of and contact information of the timber buyer. Item 4 states the governing laws that the contract will abide by: province and country. Items 5 of the STSC states that the landowners, who have the right to sell the timber, agree to sell the timber listed in the specified timber harvest plan (Item 2), to the specified timber buyer (Item 3). Item 6 provides the timber buyer with authorization from the landowners to enter the land with the necessary vehicles and equipment to conduct the timber harvest.

Items 7, 8, 9, and 10 present the financial agreements between the landowners and the timber buyer. Item 7 lists all the timber species that will be harvested as specified in the harvest plan and provides the price per cubic meter that will be paid for each species. Item 8 states that the payments will be calculated using post-harvest timber measurements, as well as the name of the person that will conduct the measurements. Item 8 describes the dates that the landowners will be paid on. Item 10 states that all timber marked by the buyer or included in the contract shall remain on the property of the landowners until it is paid for.

Item 11 presents the dates that the contract will be viable for. Item 12 frees the landowners from any liability caused by the timber buyer’s harvest operation within the timber sale area during the time that the contract is valid for. Item 13 allows the landowners to suspend the contract at any time if the sales contract or timber harvest specifications are violated. Item 14 states that any amendments to the contract must be written, dated, signed, and witnessed. Item 15 specifies the performance bond that the timber buyer must post prior to commencing with the timber harvest. Item 16 is the final item of the contract, and includes the name, signature, and date of the witnesses, landowners, and the timber buyer.

Smallholder Forest Management Plan Template

Directions: Click the tabs with the grey coloured lettering to fill in the form.

1. Forest Site Name:

Forest site name

2. Landowner Names:

Click box to enter first name	Click box to enter last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name

3. Landowner Contact Information:

Primary contact name:	First name Last name
Phone number:	Phone number
Hamlet	Hamlet name
City/Town	City/town name
District	District name
Province	Province name

4. Plan Author Names and Contact Information:

Name:	First name Last name
Organization:	Organization name
Phone number:	Phone number
Email address:	Email
Name:	First name Last name
Organization:	Organization name
Phone number:	Phone number
Email address:	Email

5. Forest Description:

General forest description	
Buildings/structures on site	
Existing roads	
Water features	
Special sites	
Property history	
Total ownership area (ha):	Total hectares
Total forest area (ha):	Total hectares
Area covered by the plan (ha):	Total hectares

6. Landowner Management Objectives:

1	Describe management objective
2	Describe management objective
3	Describe management objective
4	Describe management objective
5	Describe management objective
6	Describe management objective
7	Describe management objective
8	Describe management objective

7. Description of Forest Stands:

Stand number/name:	Stand number/name
Stand history:	Stand history
Slope/Elevation:	Slope/Elevation
Species composition summary:	Species Composition
Summary of size classes:	Size classes
Summary of heights:	Heights
Stocking level:	Stocking level
Specific stand goals:	Stand goals
Desired future stand conditions:	Desired future conditions
Summary of future stand management activities:	Stand management activities

41.b Papua New Guinea Smallholder Forest Management Template

Stand number/name:	Stand number/name
Stand history:	Stand history
Slope/Elevation:	Slope/Elevation
Species composition summary:	Species Composition
Summary of size classes:	Size classes
Summary of heights:	Heights
Stocking level:	Stocking level
Specific stand goals:	Stand goals
Desired future stand conditions:	Desired future conditions
Summary of future stand management activities:	Stand management activities

41.b Papua New Guinea Smallholder Forest Management Template

Stand number/name:	Stand number/name
Stand history:	Stand history
Slope/Elevation:	Slope/Elevation
Species composition summary:	Species Composition
Summary of size classes:	Size classes
Summary of heights:	Heights
Stocking level:	Stocking level
Specific stand goals:	Stand goals
Desired future stand conditions:	Desired future conditions
Summary of future stand management activities:	Stand management activities

8. Forest Sketch Map:

9. Forest Stand Photographs:

Stand name/number

Stand name/number

Stand name/number

10. Forest Management Activities Calendar:

Year: 2020

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Week 1												
Week 2												
Week 3												
Week 4												

Year: 2021

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Week 1												
Week 2												
Week 3												
Week 4												

Year: 2022

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Week 1												
Week 2												
Week 3												
Week 4												

Year: 2023

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Week 1												
Week 2												
Week 3												
Week 4												

Year: 2024

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Week 1												
Week 2												
Week 3												
Week 4												

11. Forest Management Plan Agreement:

This page signifies an agreement between the forest landowners the authors of the forest management plan. The agreement is that the above management plan accurately describes the current conditions of the landowner's forest, their management objectives for their forest, and the selected management activities to achieve the specified management goals of the landowners. This agreement is not a binding legal contract between the landowners and the plan authors. It is only a guide to aid the landowners in implementing future forest management plan activities.

Landowner Signatures:

Name:	Signature:	Date:
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.

Plan Authors Signatures:

Name:	Signature:	Date:
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.

Papua New Guinea Small-scale Reduced Impact Logging Code of Practice

Prepared for activity 3.3 of the ACIAR Project
FST/2016/153 ‘Enabling Community Forestry in PNG’

By,
Micah Scudder, Charles Tsiritsi, and Grahame Applegate
June 2020

The following 12 logging codes of practice have been developed for small-scale timber harvests in Papua New Guinea. The purpose of the 12 codes is to reduce potential negative impacts on the environment from timber harvests, improve logging operator safety, and to improve the efficiency of the timber harvests.

1. **Minimum cutting diameter of harvest trees**: 50 cm DBH

2. **No trees should be harvested within designated buffer zones**. These buffer zones are for cultural areas, lakes/lagoons/shoreline/water storage area, and watercourses. The buffer zones should be clearly marked with flagging. The colour of the flagging should be different than the colours selected for tree marking.
   - Cultural areas = buffer of 30 m.
   - Lakes/lagoons/shoreline/water storage areas;
     - Slope < 17% = buffer of 50 m.
     - Slope > 17% = buffer of 100 m.
   - Watercourse:
     - Class 1 stream (Width of stream base > 20 m) = buffer of 30 m on each side.
     - Class 2 stream (Width of stream base is 10 – 20 m) = buffer of 20 m on each side.
     - Class 3 stream (Width of stream base < 10 m) = buffer of 10 m on each side.

3. **Tree marking**: Trees to be harvested are marked with paint and include a selected symbol for the appropriate felling direction. The felling direction should be determined by identifying the direction that will best avoid damage to other trees. If possible, trees to be harvested nearby should be felled into the same gap. The stump height that the tree is to be cut at should also be marked. Stump heights should be minimized to capture a greater volume of timber. Leave trees that are near the trees to be harvested should be marked with a different colour of paint or a different colour of flagging.

4. **Timber harvest gap sizes**: Should be limited to 2-3 trees.

5. **Vine and liana cutting**: All vines and lianas existing on trees to be harvested should be cut 3-6 months prior to the harvest. This should occur at the same time the trees are marked.

6. **Timber harvest sketch map**: Should be prepared to clearly identify the harvest area, harvest trees, buffer zones, and ingress/egress areas for accessing the site. This sketch map is for the benefit of the harvesting/milling business to aid in their planning.

7. **Landowners notice of harvest activities**: Landowners should be given notice of the expected dates that the timber harvest is to occur prior to implementation.

8. **Personal protective equipment (PPE)**: All personnel participating in the harvest and milling operations should wear appropriate PPE: Safety helmets, ear protection, eye protection, high-visibility vest, long pants, chaps if operating a chainsaw, and boots.

9. **Fuel/oil storage**: All fuel, oil, and other chainsaw/portable mill fluids should be kept in securely closed containers. Care must be taken to prevent spillage during re-fuelling.

10. **Refuse disposal**: All refuse should be removed from the site once the operations have been completed. The refuse should be deposited at the appropriate dump or recycling site.

11. **Cost analysis**: Forestry extension workers should work with the harvesting/milling business to assess operational costs of each harvest to improve future harvest plan estimates.

12. **Post-harvest assessment**: Forestry extension personnel should conduct a post-harvest assessment to determine if the logging code of practice has been followed and that payments have been made to the landowner for timber harvested. If parts of the harvest operation need improvement, this should be conveyed to the harvesting/milling business and addressed in any future small-scale RIL training.

Papua New Guinea
Small-scale Timber Harvest Plan Template

Directions: Click the tabs with the grey coloured lettering to fill in the form.

1. Timber Harvest Name & Proposed Date:

Timber harvest name
Click or tap to enter a date.

2. Landowner Contact Information:

Primary contact name:	First name Last name
Phone number:	Phone number
Hamlet	Hamlet name
City/Town	City/town name
District	District name
Province	Province name

3. Plan Author Names Contact Information:

Primary contact name:	First name Last name
Organization:	Organization name
Phone number:	Phone number
Email address:	Email

4. Landowner Objective for Timber Sale

Timber sale objective

5. Description of forest stand to be harvested:

Stand number/name:	Stand number/name
Stand history:	Stand history
Slope/Elevation:	Slope/Elevation
Species composition summary:	Species Composition
Summary of size classes:	Size classes
Summary of heights:	Heights
Stocking level:	Stocking level

6. Timber Harvest Description:

Type of harvest:	Choose an item.
Species to be removed:	Species list
Volume to be removed:	Volume estimate
Number of trees to be removed:	Number of trees estimate

7. Timber Harvest Notes:

Insert notes that describe how the timber harvest shall be conducted. This includes the tree species and volumes that will be harvested, how these trees are marked, the designated landing sites for the portable saw mills, how the buffer zones and special sites are marked, how the property boundaries are marked, and the designated access points for the timber harvesters/buyers.

8. Timber Harvest Checklist:

Check:	Description:	Date completed:
☐	Landowners informed of all harvest activities and dates.	Click or tap to enter a date.
☐	Vines and lianas on harvest trees cut 3-6 months before harvest.	Click or tap to enter a date.
☐	Property boundaries marked.	Click or tap to enter a date.
☐	Buffer zones and special sites marked.	Click or tap to enter a date.
☐	Harvest trees marked.	Click or tap to enter a date.
☐	Harvest area assessed for hazards and marked.	Click or tap to enter a date.
☐	Timber sale contract signed by landowners and timber buyers.	Click or tap to enter a date.

9. Timber Harvest Sketch Map:

10. Post-harvest Timber Volume Measurements:

Log number:	Species:	Diameter (cm)	Length: (m)	Volume (m^3)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
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39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				

11. Timber Harvest Cost Analysis:

Name:	Organization:	Job Title:	Hours Worked:	Hourly Wage:

12. Timber Harvest Before/After Photographs:

Before:

After:

Smallholder Timber Sale Contract Draft Template

Note: This document is solely for the purpose of an educational training exercise. It should not be used as an actual contract of sale. Legal council should be sought for all timber harvest transactions. None of the project partners for ACIAR Project FST/2016/153, bear responsibility for any use of this document beyond educational training purposes.

Directions: Click the tabs with the grey coloured lettering to fill in the form.

1. Forest Site Name:

Forest site name from Forest Management Plan

2. Timber Harvest Plan Name and Proposed Date:

Timber harvest name from Timber Harvest Plan
Click or tap to enter a date.

3. Agreement entered on this date: Click or tap to enter a date..

Between the following landowners:

Click box to enter first name	Click box to enter last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name
First name	Last name

And the following timber buyer:

Primary contact name:	First name Last name
Phone number:	Phone number
Hamlet	Hamlet name
City/Town	City/town name
District	District name
Province	Province name

4. This agreement shall be governed by the laws of:

Province:	Province name
Country:	Country name

5. The landowners, who have the right to sell, agree to sell to the timber buyer, who agrees to buy all the timber that has been designated in the Timber Harvest Plan (Item 2).

6. The landowners authorize the timber buyer and the timber buyer's employees to enter the landowner's land with the necessary vehicles and equipment to perform the logging operation.

7. The timber buyer agrees to pay the landowners the following prices for each cubic meter of timber removed:

Timber species	Price per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
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Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter
Timber species name	Kina per cubic meter

8. The payments will be calculated using post-harvest timber volume measurements conducted by Name of person and/or entity that will be conducting the post-harvest timber measurement**, and recorded in item 10 of the Timber Harvest Plan.**

9. The method and time of the payments to the landowners shall be made as follows:

Click or tap here to enter text.

10. All timber marked or included in this contract shall remain on the property of the landowners, until the timber is paid in full.

11. This agreement will be in affect from Click or tap to enter a date.**, to** Click or tap to enter a date.**, after which time the contract will become null and void unless a written extension is granted by the landowners.**

12. The landowners are free from responsibility for any property damage, injury, or death caused by the timber buyer's logging operation in the timber sale area during the time tenure of this agreement.

13. The landowners may suspend timber harvest operations if the conditions of this sales contract are violated, or if the timber harvest specifications (See Timber Harvest Plan Items 6, 8, and 9) are violated.

14. Any modifications to this contract must be written, dated, signed, and witnessed.

15. Prior to commencing the harvesting operations, the timber buyer shall post a performance bond with Name of entity that will hold the performance bond**, in the amount of** Amount of money required for the performance bond **Kina.**

16. In witness thereof, the landowners and the timber buyer have executed this agreement on this day: Click or tap to enter a date.

Witnesses:

Name:	Signature:	Date:
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.

Landowner Signatures:

Name:	Signature:	Date:
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.

Timber buyer Signatures:

Name:	Signature:	Date:
First name Last name		Click or tap to enter a date.
First name Last name		Click or tap to enter a date.

Improved Management of the Eco-forestry System

Final Report prepared for activity 3.5 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder & Grahame Applegate
June, 2021

1 Introduction:

This report responds to project activity 3.5 'Develop an improved management system for eco-forestry/small-scale forest management.' The methods and results for this activity are a combination of activities 3.1, 3.2, 3.3, 3.6, and 3.7, as well as an assessment of past eco-forestry operations, and a discounted cash flow (DCF) analysis of portable sawmill operations.

2 Methods:

2.1 Assessment of past eco-forestry operations:

The assessment of the past eco-forestry operations was conducted with a literature review, interviews with key informants, and a thematic analysis of the findings. The detailed methods of this assessment are presented in Scudder et al. (2018), which is in Appendix 43.

2.2 DCF analysis of portable sawmill operations:

The DCF analysis of portable sawmill operations utilized a mixed-methods approach. Key informants were interviewed from an eco-forestry NGO in Madang, from forest product businesses in Madang, and from staff at the Timber and Forestry Training College (TFTC). The data collected from the interviews was placed into a DCF model using Microsoft Excel software and Monte Carlo risk analysis simulation techniques. The detailed methods of this assessment are presented in Scudder et al. (2019c), which is in Appendix 45.

2.3 Small-scale wood product value adding opportunities analysis:

An analysis on value adding opportunities was undertaken to identify potential options for improving the low financial returns expected from milling rough-sawn lumber with portable sawmills. For this investigation, we conducted a production cost analysis of value-add wood products. The detailed methods of this assessment are presented in section 2.2 of the report for project activity 3.7, titled, 'Value Adding Opportunities for Community Timber in Local Sawmills in Lae.' This report is in Appendix 49.

2.4 Assessment of the existing timber markets available to FROs:

This assessment on the existing timber markets available to FROs investigated the financial returns being received in the formal and informal timber markets. This assessment is described in the report for activity 3.6, which is in Appendix 44. The formal timber market is characterized by industrial-scale logging, with most of the logs being exported. The formal timber market was assessed with a cash flow analysis of log export revenue distributions to FROs. The detailed methods of this assessment are presented in Scudder et al. (2019b), which is in Appendix 46. The informal timber market is characterized by small-scale harvests and milling performed with portable sawmills and sold in local markets. This market is referred to an informal because most of the participants to not apply for a TA, and therefore operate outside of the view and regulations of the Papua New Guinea Forest Authority (PNGFA). The informal market was assessed with a case study analysis. The detailed methods of this case study are presented in Scudder et al. (2019a), which is in Appendix 37.

2.5 Assessment of the constraints of the Timber Authority harvest permit:

An assessment on the constraints of the timber authority (TA), was conducted to identify how the existing TA regulations hinder the ability of forest resource owners (FROs) from accessing formal wood product markets. This assessment was conducted for activities 3.1 and 3.2 of the project. The detailed methods of this assessment are presented in the report titled, 'Constraints of the Timber Authority Harvest Permit and Options for Improvement.' This report is in Appendix 36.

2.6 Development of small-scale forest management plans and logging code of practice:

The design for the small-scale forest management plans and logging code of practice was conducted in project activity 3.3. The detailed methods of this process are described in this report, titled, 'Reduced Impact Logging Guidelines for Small-scale Forestry in PNG.' This report is in Appendix 39.

3 Results:

3.1 Eco-forestry assessment:

The research found that the eco-forestry model for small-scale native forest management was unsuccessful. This model was based on Indigenous communities using portable sawmills to produce sustainably certified rough-sawn lumber for export. The research found that this approach to small-scale forestry was not financially viable in the long run despite massive subsidization by the NGOs. The Indigenous communities did not possess the required milling and business capacities for meeting the quantity and quality production targets necessary for financial viability. The eco-forestry organisations assumed that quantity targets could be met by increasing the number of portable sawmill operations. This ultimately over-extended the eco-forestry organization's ability to provide adequate facilitation services to the portable mill operators. The research found that increasing the number portable sawmills is not an efficient approach for increasing economies of scale, because modern industrial-scale sawmills are able to produce the same products at lower costs. It was determined that future portable sawmill operations in PNG should re-focus to serve domestic markets. Furthermore, future portable sawmill operators should complete necessary training prior to implementing commercial milling activities. In addition, harvesting and milling projects should be assessed for financial feasibility prior to implementation to filter out non-viable projects.

3.2 Financial analysis of portable sawmill operations:

The research results revealed that using portable sawmills to produce rough-sawn lumber is highly unlikely to be financially viable if an even distribution of the trees at the harvest site were milled. The variable processing costs of portable sawmills are very high relative to the average sales prices of rough-sawn lumber. During the analysis, it was discovered that only a small selection of timber species had per unit sales prices that were greater than the per unit production costs. This finding illustrated that the species composition of the harvest site was a critical factor for achieving financial viability. The high level of species diversity of PNG's forests emphasized the importance of harvest site selection. Harvest site selection was also affected by the distance to market due to high lumber transportation costs.

The research also discovered that maximizing daily log input and A grade lumber recovery were also critical factors for achieving financial viability with portable sawmills. The advent of a desired timber species composition at the harvest site did not guarantee financial viability. This finding highlighted the importance of competency-based training for small-scale timber harvests and portable mill operations.

We concluded that the financial viability of portable sawmill operations could be greatly improved if further value was added to the rough-sawn lumber.

3.3 Small-scale wood product value adding opportunities:

We determined that the value-add wood products that offered the best potential opportunities are T&G wood flooring (made from *Pometia pinnata*, and *Intsia bijuga*), weatherboard (made from mixed softwoods, and architrave made from mixed hardwoods. We found that these products had the largest profit margins and require a larger volume of use per housing unit relative to D-mould. Structural lumber products that are in demand should still be produced, but we recommend that the cutting patterns for milling the logs focus on producing flooring, weatherboard, and architrave pieces. In addition, focus on these value-add products can act as a hedge against the larger sawmills that are able to produce rough-sawn lumber products at lower costs.

We suggest that value-add wood product manufacturers strive to produce the highest quality T&G flooring and weatherboard within the target market. Opportunities for improving product quality can be achieved with the purchase of modern machining equipment, improved drying and grading standards, and improved chemical treatment procedures. We recommend that further research be conducted to identify the specific product attributes desired by the target market related to these quality improvement opportunities. We also recommend that further research be conducted to identify the service attributes desired by the target market. Some examples of service attributes are; installation instructions included with the product; installation training; product delivery; prices; payment options; and sales reps being available.

In addition to the products suggested above, we also suggest that further research be conducted into identifying additional market opportunities for the wood product residues/waste materials. One product option that has been identified for the short-length timbers/offcut materials is foldable, portable and do-it-yourself (DIY) furniture such as student desks small tables and stools (Ozarska et al. 2019). Research by Ozarska et al. (2019), in collaboration with TFTC, completed a DIY furniture pilot project utilizing previously unwanted short-length timbers. Further research should be conducted on the potential market opportunities for these products. Firewood is an additional product that has been identified as an option for utilizing the wood slabs, and lumber offcuts (Yakuma 2017). The residue product options for sawdust and shavings produced by the moulding machine and planer/thicknesser should also be explored.

These residues could potentially be used for charcoal production and/or sold to charcoal producers. By identifying product lines for these wood residues, additional revenue streams can be achieved, and wood product waste can be reduced.

3.4 Existing timber markets available to FROs:

In the formal timber markets, we found that the FROs received little compensation for the timber harvested on their lands, which averaged just 6% during the last decade. Almost all the value (94%) has been captured by the government and the logging industry. Furthermore, the real value of the fixed-rate royalties has been substantially eroded by the inflation. The log export duties collected by the government were calculated with a progressive tariff rate based on the FOB value of the logs. If the royalties to FROs had been calculated based on a percentage of the FOB value (8% to 20%), the FROs would have received between $267 and $668 million (real 2017 USD) in additional royalties. Unfortunately, it was not possible to determine if increased royalty rates would have caused a decline in timber harvests due to the absence of accurate logging cost and log price data. During the last decade, the PNG government has collected an average of 42% of the log values through export duties and levies. From this amount, it would have been possible to re-allocate increased royalty payments to FROs. We found that a side effect of the fixed-rate royalties was the formation of an informal sector, made up of small-scale participants operating outside of the forest policy regulations.

In the informal market, we found that FROs sold their timber to informal sector operators for immediate cash needs. Small-scale wood product manufacturers operating in the informal sector have captured most of the value of the harvested timber relative to the FROs and portable sawmill operators that only produced rough-sawn lumber. Most of the portable saw millers had not been able to acquire the financing necessary to purchase equipment that would have allowed them to process the products beyond rough-sawn lumber. One of the factors that hindered the financing of these operators is the illegal nature of the informal sector.

3.5 Constraints of the Timber Authority harvest permit

We determined that the root cause of the informal sector is the existing forest polices, which were unsuitable to the needs of the small-scale forest management operators and FROs. The existing small-scale harvest permits were designed for industrial-scale logging operations and were not the appropriate scale for the small-scale harvests that were conducted by portable sawmill operators. The research results demonstrate that that FROs sold their timber to informal sector operators for immediate cash needs. These immediate cash needs also did not fit the time-line for the existing small-scale harvest permits that took several months to receive government approval and lasted one year in duration.

4 Recommendations

The research conducted for this report activity identified several challenges experienced during past small-scale native forest management activities in PNG. The best approach for future management that improves the livelihoods of FROs will require addressing these challenges. Mitigating these challenges will necessitate; improved land use planning by FROS; FROs receiving a greater distribution of the forest resource rents from timber harvested on their lands;

increasing the market knowledge of FROs and portable sawmill operators (e.g., log values and timber species/product types demanded by construction markets); and increasing the number of small-scale manufacturers that process wood products beyond rough-sawn lumber. We made the following five recommendations to achieve these objectives:

1) Revise forest policies to require timber royalty payments to be changed to the greater of either the minimum fixed-rate as set by the Forest Minister, or to a percentage of FOB market value, as reported by Sociele Generale de Surveillance. The research conducted for this thesis identified that FROs have received an inequitable share of the forest rents from industrial logging companies and from the small-scale informal sector operators. In both cases, the market value of the harvested timber is substantially higher than the amounts paid to FROs in the past.

2) Revise forest policies to address small-scale harvest permits to reflect the scale and duration of small-scale timber harvests being conducted by portable sawmill operators. The introduction of a harvest permit that matches the operational activities of informal sector operators would give these operators the opportunity to shift their operations into the legal formal sector. Improving the legality of these operators would improve access to financing for the purchase of equipment to further process the rough-sawn lumber.

3) Explore opportunities for an extension forestry programme to serve the small-scale forestry sector. In the past, government foresters have focused their activities on harvests conducted by the industrial-scale logging companies. NGOs have previously provided forest management support to FROs, but most of them have ended their operations due to inadequate funding. The TFTC does provide some forest management and portable sawmill training to FROs, but they are limited in the scope and scale of extension forestry support that they can provide, due to limited funding. The need for extension foresters at the small-scale level is three-fold:

a. Assisting FROs in the development of forest management plans. There is a need for trained foresters to assist FROs in developing management plans that reflect FRO interests and values, are environmentally sustainable, and financially viable to implement. The eco-forestry organizations were successful in developing procedures for creating management plans for Indigenous communities. This work could be built on to develop systems for evaluating the financial viability of timber harvests prior to implementation. The complexities that can exist with customary land ownership should be addressed when developing the management plans. This should include the identification of user rights and obligations at the group level and individual level, as well as using a process for building consensus among the FROs that builds on the existing social relationships within the forest site.

b. Provide FROs with accurate knowledge of timber values and connect FROs with trained, experienced, and legal small-scale timber harvesters. Increased knowledge of fair market values and linking FROs to verified legal and capable timber harvesters would allow FROs to acquire a greater distribution of forest resource rents. Having their services marketed to FROs would also incentivise portable sawmill operators to work within the formal sector.

c. Provide capacity development training/workshops to FROs, sawmill operators, and manufacturing businesses. There is a need for improved operational capacities by all small-scale forest sector participants. Capacity development needs include; management planning; wood product market knowledge; reduced-impact-logging (RIL) techniques; improved operational efficiencies in harvesting, milling, processing; and fiscal management. Capacity development focused on improved fiscal management should address the challenge of re-investing profits back into a business while continuing to meet wontok obligations. Further research is needed to understand how both needs can be met without negatively impacting on the other.

Multiple options exist for administering and funding an extension forestry programme in PNG. Administration options include the PNGFA, other public institutions similar TFTC, small-scale forestry focused NGOs, or combination of the three. Funding options include a re-allocation of government funds collected from export log duties and levies, international publicly funded aid grants, and private donations to finance NGO efforts to support extension forestry. Further research is needed identify the scope and scale of potential forestry extension opportunities.

4) Enact forest policies that develop government-backed financial lending programs for small-scale forestry operators that have demonstrated adequate operational competency. There is a need for increased small-scale wood product manufacturing businesses, which will require financing for operators to purchase new equipment. Some examples of adequate operational competency are completed training programs with valid certificates, validated operational hours of equipment use, an approved businesses plan, and legal forest industry participant (FIP) verification. The TFTC has been the primary option for portable mill and value-add processor training in PNG. Training is provided for students at TFTC, in the city of Lae, and at alternative sites for large groups when arranged with TFTC staff.

5) Further research and marketing of the applicability of lesser-known timber species to reduce the potential of over-harvesting a small selection of timber species. During the addressment of research questions two and four, it became evident to the author that past small-scale timber harvests have primarily focused on a small selection of timber species. The cause has been high market demand for these species that has resulted in these timber species receiving the highest per unit rough-sawn lumber prices in the small-scale timber markets. Most of the lesser-known species received per unit rough-sawn lumber prices that were lower than the variable portable sawmill production costs. Identifying alternative timber species with similar product applicability and disseminating the market knowledge should be pursued to reduce the harvesting pressure of the most desire species.

Addressing these recommendations will result in what is our opinion, the best approach to small-scale native forest management in PNG for improving forest landowner livelihoods. FROs would gain assistance from trained foresters to develop forest management plans that reflect their interests, values, social relationships, and land use rights/obligations. All timber harvests and portable milling operations would be pre-assessed for financial viability and conducted by trained operators. Revisions to forest policy would allow for a greater number of saw millers to expand into additional wood processing activities. Increased competition in the small-scale wood processing sector and revisions to timber royalty rates would allow for FROs to capture a greater portion of resource rents from timber harvested on their lands. In locations where timber harvests and milling are determined to be financial unfeasible, lumber would only be milled for FRO homes and other community buildings. Profit generating activities for these locations would be focused on generating revenue from non-timber forest products.

If these recommendations are not adopted, it is likely that the current approach to small-scale forest management will continue. Most small-scale timber harvests would likely occur in the informal sector, with the small-scale manufacturers capturing most of the timber value relative to the FROs. If the government moves forward with a log export ban, it is expected that informal sector will expand as FROs that previously received timber royalties from industrial logging companies seek alternative markets for their timber. It is also probable that timber harvests would continue to focus on small selection of species currently desired by the market until all accessible areas have been harvested.

5 Conclusion:

In the past, forest management in PNG has focused on large-scale timber harvests for log exports to achieve economic growth. There was an interest in identifying small-scale native forest management models that could provide greater benefits to FROs than they had received from the timber harvests conducted by industrial logging companies. The small-scale management model that had been primarily practiced in the past was eco-forestry, but the effectiveness of this approach was unknown. The objective of this research was to identify the best approach to small-scale native forest management in PNG to improve FRO livelihoods.

It was found that the past eco-forestry management model was not successful. This model ultimately failed because it was not financially viable, and the indigenous participants were not able meet the quality and quantity lumber production targets. We found that using portable sawmills in tropical forests can be financially viable if trained operators are used and only high-value timber species is harvested and milled. However, only a small selection of timber species was determined to be financially viable and tropical forests have a high level of timber species diversity. If saw millers continue to only harvest these species, it is likely that the forest will continue to be high-graded until all the accessible high-value trees have been removed. The research found that this challenge could be mitigated if the portable saw millers harvested additional lesser-known species and further processed the rough-sawn lumber to produce products with higher value. Most of the saw millers operate within the informal sector, which is not technically legal and impedes their ability to access financing. Revisions to the existing forest policy harvest permits that allow these saw millers to become legal operators could mitigate the financing challenge. Revising forest policies to improve the timber royalty rates could increase the portion of timber revenues collected by the FROs. We concluded that making these changes would be the best approach to an improved eco-forestry management framework.

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The failure of eco-forestry as a small-scale native forest management model in Papua New Guinea

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ABSTRACT

Deforestation and forest degradation are problems common to many tropical countries, including Papua New Guinea (PNG). These problems are often a result of the environmentally unsustainable logging practices of industrial logging companies. Beginning in the 1990s, six organizations attempted to mitigate the deforestation and forest degradation occurring in PNG by facilitating small-scale native forest management by Indigenous forest landowners. All six organizations utilized an 'eco-forestry' approach, involving selective harvesting of timber combined with the milling of timber by Indigenous forest landowners using portable sawmills. The lumber produced was sold into local and international markets as sustainable certified under Forest Stewardship Council (FSC) principles. The use of portable sawmills was also intended to provide the landowners with a greater financial return compared to the timber royalty payments they could receive from logging companies. This study used a literature review and interviews with key informants from the eco-forestry organizations and the PNG Forest Authority to assess the effectiveness of variants of the portable sawmilling model. We found that each of the six organizations were unsuccessful in developing a financially viable model for small-scale native forest management by Indigenous forest landowners in PNG. All the Indigenous landowners were unable to continue their portable sawmill operations once the donor funding of the eco-forestry organizations ceased. In addition, the operators of portable sawmills struggled to produce lumber that met the quality and quantity demands of buyers, who ultimately ceased purchasing the lumber. Furthermore, the Indigenous landowners struggled to adhere to the FSC principles, resulting in a loss of FSC certification. The study identifies a need for a new small-scale native forest management model in PNG. We recommend that future research involve collaboration with private sector businesses and professionally trained operators to inform the development of a small-scale forest management model which is financially profitable while also adhering to the principles of eco-forestry.

1. Introduction

Papua New Guinea (PNG) has one of the largest remaining continuous areas of tropical forest in the world. There are approximately 29 million hectares of forest with 97 percent of the forest held under customary land ownership by Indigenous clan groups (PNGFA, 2009). Large-scale industrial logging companies operating in PNG export approximately 90 percent of the logs harvested in the country (PNGFA, 2009). Just over 3.4 million m^3 of non-coniferous logs were exported from PNG in 2016 (SGS, 2017). This amount represents 8.5 percent of total non-coniferous log exports from all tropical countries in the world in 2016 (ITTO, 2017). The PNG Government imposes export duties on exported logs, which totalled approximately $95.5 million USD in 2016 (SGS, 2017). The customary landowners receive royalty payments as compensation for the harvested timber, which varies between $3.30 and $11.55 per m^3 in 2016 USD, depending on the tree species (NFS, 2011).

The harvest methods of the large-scale logging companies operating in PNG have been widely criticised, especially in respect to the widespread environmental damage resulting from noncompliance with the PNG Logging Code of Practice (PNGFA, 1996), (e.g. Bun and Scheyvens, 2007; Fox et al., 2011; Bun, 2012). In addition, the timber harvests have resulted in social inequalities due to the royalty payments received by the landowners being disproportionately small relative to the value of the timber being removed. Furthermore, the system for distributing royalty payments to landowners lacks financial transparency, causing landowners to question if they have been paid the amounts they were owed (Bird et al., 2007). These issues provided the impetus for PNG's customary landowners and supporting non-governmental organizations (NGOs) to explore alternative forest management methods such as 'eco-forestry.'

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'Eco-forestry, as a form of forest management is poorly defined with limited performance metrics established. It has been described by the Food and Agricultural Organization (FAO) of the United Nations as an ecologically sustainable and economically viable alternative to conventional logging. The key principles of eco-forestry were derived from the 'Sustainable Forest Management' (SFM) and the 'Ecosystem Approach' (EA) to forest management (Scialabba and Williamson, 2004). The 15 principles of SFM were originally promulgated by outputs of the United Nations Conference on Environment and Development (UNCED, 1992). The objectives of the 15 SFM principles was to provide guidance for the management, conservation and sustainable development of all forest types to meet the ecological, economic, social, cultural and spiritual needs of society (Wilkie et al., 2003). The 12 principles of the EA approach to forest management also originated as an outcome of the UNCED, and were developed by the Convention on Biological Diversity to provide a holistic approach to forest management aimed at conserving ecosystem services (CBD, 2000). While SFM and the EA had different starting points - forest management versus conservation ecology - they are sufficiently similar to be combined for planning purposes (Wilkie et al., 2003; Sayer and Maginnis, 2005). Thus, eco-forestry became a forest management model based on the principles of these two forms of forest management. The Commission on Sustainable Development (CSD) was established by the United Nations General Assembly to ensure effective follow-up of the outputs of UNCED. It was recognized by the CSD that the development of criteria and indicators (C&I) would be a crucial step for evaluating the performance of sustainable forest management (Szaro et al., 2005). Third party sustainability certification emerged as a tool for establishing C&I and verifying the occurrence of the required indicators (Sayer and Maginnis, 2005). In PNG, the primary organization for third party certification is the Forest Stewardship Council (FSC). The current FSC principles, criteria, indicators and verifiers for PNG were established in 2010 (FSC, 2010).'

In PNG, eco-forestry as a forest management model has been linked to the use of portable sawmills. Beginning in the 1970s, church groups and NGOs imported portable sawmills so that Indigenous communities could mill lumber for their own needs. Advances in the mill designs in the 1980s improved portability, resulting in widespread adoption throughout the country (Bun and Scheyvens, 2007; Holzknecht et al., 2012). Beginning in the 1990s, multiple NGOs facilitated small-scale native forest management which followed the principles of eco-forestry. The NGOs incorporated portable sawmills into this forest management model, with the mills being operated by the Indigenous forest landowners. While the use of portable sawmills as an alternative to conventional logging and log processing for rural development has been practiced in Vanuatu, the Solomon Islands, the Philippines and Brazil (World Bank, 1996), PNG is the only tropical country that has specifically linked eco-forestry and portable sawmills as a forest management model. For the remainder of this paper the entities involved in eco-forestry projects in PNG will be referred to collectively as the 'eco-forestry organizations.'

There have been few rigorous attempts to critically assess the success of eco-forestry projects in PNG, and whether portable sawmills are an appropriate technology for use in such projects. In addition, there is a lack of information about whether there are opportunities to scale-up the existing small-scale forest management activities utilizing the eco-forestry management model with portable sawmills. The aim of this study was to assess the effectiveness of eco-forestry using portable sawmills as a model for small-scale native forest management by PNG's Indigenous landowners and determine if it is a viable model that can be further developed and scaled-out to additional communities in the country. The criteria by which we assess the of the eco-forestry organizations in this study were; (1) the financial viability of their operations; (2) their ability to accomplish their management objectives; and (3) their ability to adhere to the principles that the eco-forestry management model was based on.

2. Methods

2.1. The eco-forestry organizations

Six eco-forestry organizations have been involved in facilitating small-scale forest management activities with Indigenous forest landowners in PNG using portable sawmills since the early 1990s. Most of these organizations were structured as NGOs. Only two of these organizations are currently operational. They are the Foundation for People and Community Development (FPCD) and FORCERT. The eco-forestry organizations discussed in this paper were headquartered in the cites of Kimbe, Lae, Madang and Rabaul in PNG (Fig. 1). Key features of these organizations are presented in Table 1.

2.2. Data collection

Data was collected from a literature review and interviews with key informants. A literature search was first conducted using Google Scholar, JSTOR and ProQuest search engines to locate relevant journal articles, conference papers and reports discussing eco-forestry organizations in PNG. The keywords used in the literature search were; Papua New Guinea; eco-forestry; and portable sawmills. The initial literature search yielded 101 documents. Of these documents, only 10 provided information specific to the operations of the eco-forestry organizations. Three trips were made to PNG in 2016 to the cities of Lae, Madang and Port Moresby to conduct interviews with key informants from the eco-forestry organizations and the PNG Forest Authority. During these visits, additional documents relating to the eco-forestry organizations were collected, comprising four external evaluations of the eco-forestry organizations, a strategic plan for one of the eco-forestry organizations and eight operational reports produced by the eco-forestry organizations. The eight operational reports were only available as paper-copies and were in the PNG Forest Research Institute library in Lae and from current or former employees of the eco-forestry organizations.

An interview protocol was designed based on the preliminary results of the literature review. The interview questions were designed to identify the management activities implemented by the eco-forestry organizations, their accomplishments, the destinations of the milled lumber, and the funding received to implement the eco-forestry activities.[1] The interview format was similar for all interviewees. The initial question asked during the interview was; 'What are the specific activities that were implemented by (the NGO being interviewed) to facilitate eco-forestry with the Indigenous landowners'? Follow up questions focused on; training provided to the landowners; if forest management plans had been completed; lumber volumes produced; transporting the lumber to market; lumber sales; accomplishments; challenges experienced; and sources of funding for NGO activities. All the interviews were conducted by the first author, with hand-written notes taken during the interviews. The length of the interviews varied between 30 min and two hours. The initial interviews were with four current and former employees of one of the eco-forestry organizations, the Foundation for People and Community Development (FPCD). Only one current employee of FORCERT was willing to participate in an interview. This person was also a former employee of IRECDP. It was not possible to conduct interviews with three of the eco-forestry organizations discussed in this paper because these organizations had ceased their operations and no former employees could be contacted. Additional interviews were conducted with 10 employees of the PNGFA that had knowledge of the past operations of the eco-forestry organizations. Details of the key informants interviewed for the study are presented in Table 2.

[1] Total funding estimates were collected from four of the eco-forestry organizations. Partial estimates for two of the organizations were collected from reports and news articles. All the data estimates were inflated to 2016 USD values. To address privacy concerns, data related to specific organizations and the sources utilized has been kept confidential.

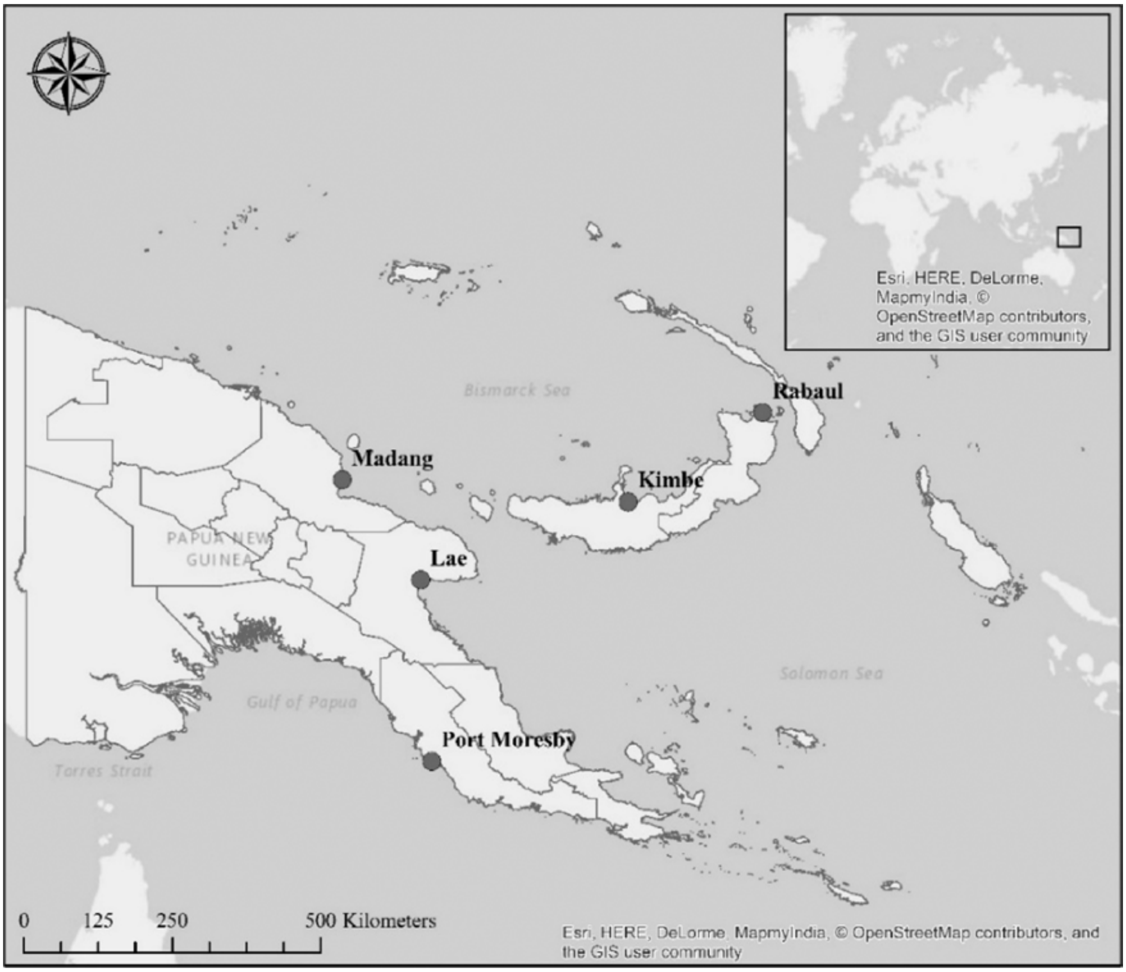

Fig. 1. Data collection sites and headquarter sites for the eco-forestry organizations and the PNGFA.

2.3. Data analysis

We completed our data analysis in two steps. The first step was a summary of each of the six eco-forestry organizations is provided in the following sections. The summaries outline each organization's: a) year of commencement, location in PNG and objectives, b) management activities, c) accomplishments, and d) year of ceasing operations and why.

The second step was a thematic analysis to identify patterns in the data using methods outlined by Boyatzis (1998). The materials used in the thematic analysis were the ten documents identified in the literature search, the four external evaluations of the eco-forestry organizations, the strategic plan of one of the eco-forestry organizations, the eight operational reports produced by the eco-forestry organizations and the notes written by the first author during interviews. A thematic code was developed by the first author from a sub-sample of these materials. The sub-sample was the four external evaluations of the eco-

Table 2
Description of the key informants interviewed.

Organization	Number of people	Interviewee expertise
PNG Forest Authority		
National headquarters	4	Forest management
Madang Provincial office	3	Forest management
Lae Forest Research Institute	3	Forest management
Eco-forestry organizations		
FORCERT	1	NGO management
Foundation for People and Community Development	4	NGO & forest management
Islands Region Environmental & Community Development Programme	1	NGO management

Table 1
Key features of the eco-forestry organizations.

Name	Start year	End year	Institutional framework	Number of mills
Village Development Trust	1990	2010	NGO	4
Pacific Heritage Foundation	1992	2003	NGO	12
Islands Region Environmental & Community Development Programme	1995	2001	NGO/Government	40
PNG Eco-forestry Programme	2002	2005	Government	15+
Foundation for People and Community Development	1996	–	NGO	6
FORCERT	2004	–	NGO	40

Table 3
Thematic code labels and descriptions.

Thematic code label	Description of thematic code
Group one themes	Did the eco-forestry organizations provide these services?
Community development	Construction of buildings and training to improve health of community.
Forest management plan	Completed forest management plan with inventory, objectives and activities.
Sawmill operator training	Trained portable mill producers in the use and maintenance of portable sawmills.
Business training	Trained portable mill producers in business fundamentals.
FSC certification	Assisted portable mill producers in getting FSC certification.
Harvest set-up	Marked harvest trees and appropriate sites to set-up the sawmills.
Oversee harvest and milling	Were present during harvest and milling operations to assist portable mill producers.
Marketing and sales of lumber	Identified foreign buyers for the milled lumber and completed sales contracts.
Operated CMU	Aggregated the lumber milled by multiple portable mill producers at a lumber yard.
Group two themes	Did the eco-forestry organizations experience these challenges?
Business management	Maintaining the business functions of the organization.
Financial sustainability	Loss of donor funding or inability to generate revenues required for operations.
Sales requirements (quality)	Lumber quality did not meet the requirements of the buyers.
Sales requirements (quantity)	The volume of lumber produced did not meet the production demands of the buyers.
Maintaining FSC certification	Failure to consistently meet the FSC certification requirements.
Overextension of resources	Not enough employees/resources to meet the needs of the portable mill producers.
Group three themes	Did the portable mill producers experience these challenges?
Financing	Landowners could not obtain financing for a portable sawmill.
Lumber quality targets	Lumber quality did not meet the requirements of the buyers.
Production targets	Failure to meet lumber production targets set by the eco-forestry organizations.
Sawmill maintenance	Inability to get proper mechanical maintenance or spare parts for sawmills.
Transporting lumber	Transportation being prohibitively expensive due to poor road infrastructure.
Business concepts	Business concepts were difficult for portable mill producers to comprehend.

forestry organizations. Twenty-one recurring themes were identified during the review of the sub-sample. The twenty-one themes were classified into three groups; (1) eco-forestry organization management model activities, (2) challenges experienced by the eco-forestry organizations, and (3) challenges experienced by portable mill producers. From these themes, twenty-one thematic codes were developed (Table 3). All the materials used in the thematic analysis were reviewed by the first author to determine the presence or absence of the thematic codes for each eco-forestry organization. Patterns were identified from thematic codes that had the highest occurrences among the six eco-forestry organizations.

3. Results

3.1. Village development trust

The Village Development Trust (VDT) is an NGO established in 1990 in Lae in Morobe Province. VDT's primary objective was to encourage small-scale forestry with management performed by the landowners (Fox et al., 2011). A long-term objective of VDT was to establish a lumber yard and re-sawing facility in Lae dedicated to the production eco-forestry wood products (Bun and Scheyvens, 2007). VDT's management model facilitated eco-forestry by providing support to portable sawmill owners, but no forest management standard was ever applied (Bun and Scheyvens, 2007). VDT facilitated sales of the milled lumber to private merchants in Lae for a 10 percent commission fee (Chatterton et al., 2000). VDT was one of the first organizations to accomplish the export of eco-forestry lumber, which occurred in 1992/1993 (Chatterton et al., 2000). VDT, with the assistance of Habitat for Humanity[2], also facilitated the milling and construction of 30 homes in the Waria Valley, which lies in the south-eastern corner of the Morobe Province (Chatterton et al., 2000). A report by Fox et al. (2011) indicates that VDT was in the process of assessing a new eco-forestry project for approximately 20,000 ha of forest in the adjacent province of Madang just before it ceased all its operations in 2010. The exact reason for the VDT's cessation of operations is unknown, but it is assumed to have occurred due to a loss of donor funding support (Subendranathan, 2008; Fox et al., 2011; Nerius et al., 2011).

3.2. The Pacific Heritage Foundation

The Pacific Heritage Foundation (PHF) is an NGO that started in 1992 and was based in Rabul in East New Britain Province (Henderson, 1997; Chatterton et al., 2000). A British DIY chain store called B&Q subsidized PHF's operations (Henderson, 1997; Bun and Scheyvens, 2007; Scheyvens et al., 2007; Subendranathan, 2008). The objective of PHF was to provide B&Q with a line of certified sustainably-sourced lumber. In 1994, the PHF became the first eco-forestry organization in PNG to receive Forest Stewardship Council (FSC) certification, with 12,500 ha certified (Chatterton et al., 2000). PHF began marketing the lumber in 1995, but the certification lapsed in 1996 (Bun and Scheyvens, 2007). At its peak, the organization had 12 portable mill producers in PNG. The PHF ended its operations in 2003, due to a loss of funding and other management problems (Bun and Scheyvens, 2007; Scheyvens et al., 2007). Salafsky et al. (1998) and Subendranathan (2008) indicated that the struggles that PHF experienced were a combination of challenges, including the managerial and financial requirements needed for its operations. The organization struggled to meet the requirements for export sales including timely delivery and maintenance of the quality and quantity of the eco-forestry lumber required by the buyers. The second challenge was adhering to the FSC standards and corrective action requests, which ultimately led to the cancelation of the annual FSC monitoring visit and withdrawal of FSC certification.

3.3. Islands Region Environmental and Community Development Programme

Information on the Islands Region Environmental and Community Development Programme (IRECDP) was collected from the "End of Programme Report" (EU-IRECDP, 2001), Hunt (2002) and Scheyvens et al. (2007). The IRECDP was founded in Kimbe in West New Britain Province and operated from 1995 to 2001. The IRECDP received

[2] Habitat for humanity is a global non-profit organization that helps people build affordable homes. See www.habitat.org.

funding from the European Union's (EU) Economic Development Fund and was nominally under the administration of PNG's Department of Environment and Conservation, making it an NGO/Government hybrid. The objective of the programme was to develop income earning opportunities for landowners through sustainable forest management using portable sawmills. The management model of IRECDP utilized an 11-step process for facilitating small-scale community forestry based on management guidelines (see Annex 4 of EU-IRECDP, 2001) and lessons learned from the programme (see Salafsky, 1997). Each eco-forestry project was managed by the landowners as a village business. The "End of Programme Report for Marketing Unit" by Maniho (2001) indicated that the IRECDP utilized two central marketing units (CMUs) in East and West New Britain. These CMUs acted as timber yards and purchased 80 to 90 percent of all lumber produced by the eco-forestry projects. These CMUs were intermediaries between the eco-forestry producers and the major local buyers and overseas markets.

The accomplishments of IRECDP include the facilitation of approximately 40 eco-forestry projects throughout seven provinces in PNG. In 1998, the programme received FSC Group Certification, allowing IRECDP to determine which eco-forestry projects qualified for certified status. By the year 2000, approximately 10,000 ha of forests had received certification. In 2001, IRECDP ended their role as eco-forestry facilitators, which was determined to be phase one of the programme. It was determined that phase one was successful at initiating income earning opportunities through sustainable forest management for landowners, with the assistance of donor funds. The challenges experienced by the IRECDP were primarily related to maintaining the quality, consistency of supply and timely delivery of the eco-timber to markets. Maniho (2001) recommended that phase two of the project implement cost of production studies to identify the break-even production volumes and set monthly production targets.

3.4. PNG Eco-forestry Programme

Information on the PNG Eco-forestry Programme (EFP) was collected from the EFP annual reports for the years 2002, 2003 and 2004 (EFP, 2003, 2004, 2005). The EFP was the second phase of the EU-funded IRECDP, and received additional funding from the EU. In addition to continuing the objectives of phase one, a new objective of the second phase of the programme was to improve business intelligence and the profitability of operations. EFP managers believed that in the past, IRECDP had kept the operations competitive with subsidization, which resulted in community groups' excessive financial dependency on the programme. The EFP continued to manage the eco-forestry projects and CMUs developed by IRECDP, but also introduced new activities. A second, medium-scale project was initiated in the Western Highlands Province. This project was designed to increase economies of scale and increase value-added processing. The harvest plan for this project was based on Reduced Impact Logging (RIL) techniques estimated to produce approximately 12,000 m^3 of lumber annually, using a D7 dozer, tractor and two semi-portable mills.

Annual reports indicate that the EFP undertook a forest inventory, prepared a forest management plan and conducted operational training for the medium-scale project in the Western Highlands, but there is no information available if any harvest operations ever took place. Minimal data was found on the accomplishments related to the carry-over projects from IRECDP, but it is known that the FSC certification was withdrawn. Additional accomplishments of the EFP were the establishment of 25 nurseries, a reforestation support scheme and the drafting of a national eco-forestry policy. This policy draft was submitted to the National Forest Board in 2004 for approval, but it never resulted in changes to national legislation and remains in 'draft' form. The EFP shut down in 2005 when funding from the EU ceased. A review undertaken at the end of the programme by Ducenne and Rollinson (2005) determined that the EFP structure was not sustainable from a financial perspective because there was no organization capable of administering the programme after the EU funding was exhausted. The report indicated that the involvement of the private sector in future eco-forestry activities would be a key aspect for mitigating this funding challenge. Ducenne and Rollinson (2005, p.10) stated that "The biggest misunderstanding about eco-forestry and EFP has been to associate eco-forestry with portable mills! This has been a simplistic and incomplete assimilation of the eco-forestry concept." This view is due to the low productivity levels common with portable sawmills, and the challenges of conducting a commercial portable sawmill enterprise within the socio-cultural context of clans, tribes and wantoks.[3]

3.5. Foundation for People and Community Development

The Foundation for People and Community Development (FPCD) is an NGO that began in 1996, and was established to take over the PNG-based projects of the NGO known as the Foundation for the Peoples of the South Pacific (FSP) (Nerius et al., 2011). FSP had numerous projects in PNG related to community development. These included health, sanitation, nutrition, business, carpentry, food security, disaster preparedness and small-scale sustainable forestry projects. When the FPCD took over from FSP, the FPCD Director, Mr Yati Bun, made eco-forestry projects in Madang Province the primary objective of their activities, but continued to facilitate FSP's previous projects out of a sense of obligation (Nerius et al., 2011). The management model utilized by FPCD to facilitate the eco-forestry projects involved conducting forest inventories, preparing forest management plans, sourcing and financing portable sawmills, and marketing the milled lumber through a CMU timber yard (Nerius et al., 2011).

The FPCD conducted forest inventories and developed forest management plans for six Indigenous community groups. With the assistance of Greenpeace, the FPCD completed eco-forestry lumber exports to New Zealand and Australia (Bun and Bazakie, 2006; Bun and Scheyvens, 2007). In 2007, FPCD achieved FSC Group Certification for 2705 ha of forest (Bun and Scheyvens, 2007; Scheyvens et al., 2007). After receiving certification, an additional 64 m^3 of milled lumber was exported to Australia (Nerius et al., 2011). Due to a decline in funding, the FPCD's support for eco-forestry operations has diminished and there are currently no milling projects in operation. An external evaluation of FPCD by Nerius et al. (2011) identified several challenges. The low lumber production volume of the Indigenous communities resulted in slow or stagnant re-payments to FPCD for the previously supplied mills. The funds tied up in these repayment contracts caused a dramatic reduction in the expected number of new portable mill operations. The low level of lumber production was also a source of frustration for international buyers of the lumber, who then turned to alternative sources of FSC-certified tropical lumber. In 2012, FPCD's FSC certification lapsed. Other challenges included community disputes over the misuse of timber income, unrealistic production and profit expectations, and the lack of understanding of appropriate business practices. The external evaluation recommended that FPCD develop a stronger focus on understanding and implementing various approaches to community development and that FPCD reduce the number of projects being pursued so that the positive impacts of the remaining projects could be improved.

3.6. FORCERT

Information on FORCERT was collected from external evaluation reports completed in 2007, 2010 and 2013, as well as a strategic plan developed by FORCERT in 2015 (Titus et al., 2007; Rosenbaum et al., 2010; Ericho et al., 2013; FORCERT, 2015). FORCERT was established as an NGO in 2003 and began its operations in 2004 in Kimbe in West

[3] When translated to Tok-pidgin, wantok means 'One talk.' The term refers to the social obligations of an individual to their family, clan or community.

Table 4
Thematic analysis of the eco-forestry organizations and affiliated portable mill producers.

GROUPS	THEMATIC CODES	VDT	PHF	IRECDP	EFP	FPCD	FORCERT
Eco-forestry organization management model activities	Community development	X		X		X	X
	Forest management plan			X	X	X	
	Sawmill operator training	X	X	X	X	X	
	Business training	X		X	X	X	
	FSC certification		X	X		X	X
	Harvest set-up			X		X	
	Overseeing harvest and milling operations	X	X	X		X	
	Marketing and sales of lumber	X	X	X	X	X	X
	Operated CMU		X	X	X	X	
Challenges experienced by eco-forestry organizations	Business management		X				X
	Financial sustainability	X	X	X	X	X	X
	Sales requirements (quality)		X	X		X	X
	Sales requirements (quantity)		X	X		X	X
	Maintaining FSC certification		X		X	X	X
	Overextension of resources				X	X	X
Challenges experienced by portable mill producers	Financing					X	X
	Lumber quality targets		X	X		X	X
	Production targets		X	X		X	X
	Sawmill maintenance		X			X	X
	Transporting lumber		X			X	X
	Business concepts		X			X	X

New Britain Province. FORCERT's objective was to enable eco-forestry by providing FSC Group Certification and developing a Group Certification Service Network. FORCERT's management model focused on connecting NGOs and their portable mill producers to timber yards/ CMUs and then to the overseas timber markets. The CMUs were private enterprises that purchased "A Grade"[4] milled lumber from the portable mill producers and then exported the aggregate lumber to international buyers. FORCERT's role was to assist the landowners and eco-forestry NGOs with meeting the requirements for FSC certification. FORCERT sought to be a self-sustaining entity by charging levies on the exported timber to both the CMUs and the portable mill producers.

FORCERT's accomplishments were greatest in 2008 with 40 portable mill affiliates and 5 CMU affiliates throughout PNG. In that year, a total of 1023 m^3 of sawn timber was produced and 420 m^3 of sawn timber was exported. There were then dramatic declines in the eco-forestry lumber export volumes, which ceased altogether by the end of 2009. A review of FORCERT's external evaluation reports revealed multiple challenges. One primary international buyer of lumber from FORCERT-affiliated CMUs ceased making purchases because the quality and quantity requirements were not consistently met, and the lumber was not always properly air-dried before shipment. The CMUs stated that the problems with meeting the quality and quantity requirements were due to the portable mill producers not meeting the agreed-upon minimum annual target of 60 m^3 of "A Grade"[3] lumber. In addition, the CMUs stated that portions of the lumber supplied by producers were incorrectly graded, incorrectly measured, and labelled as the wrong species. When CMUs provided payments to the portable mill producers based on the quality and grade of the lumber provided, the producers were often upset and ceased their operations. Common problems cited by portable mill producers were obtaining financing to purchase a portable sawmill, accessing spare parts for mill maintenance, the high wages demanded by labourers for mill operations, the prohibitive cost of transporting the milled lumber to the CMU, and the lack of transparency and distrust of the privately-operated CMUs. The external evaluations of FORCERT also identified challenges in FORCERT's structure and operations. FORCERT often found itself in the position of facilitating every aspect of eco-forestry operations that were supposed to be the role of other NGOs. This cost was not anticipated and it overextended the organization's resources. The 2013 external review suggested that FORCERT direct its resources to specific member communities. FORCERT's new strategic plan is focused on forest-based community development rather than facilitating and certifying eco-forestry operations.

3.7. Thematic analysis: common factors behind the failure of the eco-forestry organizations

The thematic analysis identified the patterns in each of the three thematic code groups; (1) the management activities performed by the eco-forestry organizations; (2) the challenges experienced by the eco-forestry organizations; and (3) the challenges experienced by them and their affiliated portable mill producers (Table 4).

There were two themes present in group 1. The first theme was a focus on international marketing and sales by the eco-forestry organizations. All six of the organizations conducted marketing and sales on behalf of the portable mill producers. Four of the organizations were involved in managing the CMUs. Four of the organizations obtained FSC certification on behalf of their portable mill producers to improve the marketability of the lumber to foreign buyers. The second theme present in group 1 was a focus on training the portable sawmill producers. Five of the eco-forestry organizations provided sawmilling training and four of them oversaw the harvesting and milling operations. In addition, four of the organizations provided basic business training to the portable mill producers.

There three themes present in group 2. The first theme was financial challenges which were caused by a loss of funding and/or insufficient revenue. These financial challenges were experienced by all the eco-forestry organizations. The second theme was a struggle to fulfil export sales requirements for the quality and quantity of lumber demanded by overseas customers. This theme was present in four of the eco-forestry organizations. The third theme was the inability to maintain FSC certification, which was experienced by four of the eco-forestry organizations.

In group 3, the primary theme was the struggle of the portable mill producers to meet the quality and quantity lumber production targets. This them was present in four of the eco-forestry organizations. Ultimately, the inability to meet these production requirements led to the cessation of eco-forestry lumber exports. The factors identified as causing the low lumber production by the portable mill producers included:

[4] Interviews with eco-forestry organization employees revealed that "A Grade" lumber is of a higher quality than B grade lumber due to reduced imperfections such as knots, wane, checking, warping and cupping. The B grade lumber could be sold in domestic markets, but only the A grade lumber could be exported.

- Inability to acquire the necessary capital to access or purchase a portable sawmill, chainsaws and other required equipment;
- Inadequate sawmill training;
- Low availability of mechanical parts and low implementation of maintenance by operators;
- Limited available time due to physiological need requirements such as garden tending;
- Transport difficulties due to non-existent or poor road infrastructure and in some cases the long distance from the mill to the market;
- Lack of business skills, low knowledge of markets and poor fiscal management practices;
- Strong reliance by landowners on the eco-forestry organizations to facilitate all forest management and marketing activities; and
- Limited NGO experience in profit-generating activities, with most skillsets being forest management focused and not related to business management.

4. Discussion

We found that all six eco-forestry organizations ultimately failed to facilitate sustainable small-scale native forest management in PNG using the eco-forestry management model. Financial viability was the greatest challenge experienced by all organizations and the failure to establish a financially sustainable eco-forestry business ultimately resulted in all the organisations failing. All organizations received funding from donors to facilitate their operations over the period of two decades. Total funding was estimated to be in excess of $26.8 million (2016 USD). Some of the organizations developed revenue streams through commission or levy payments to assist with meeting operational costs. However, none of these revenue streams were sufficient to enable the eco-forestry organizations to attain financial sustainability and ultimately, they all ceased to operate when the donor funding declined. The cessation of operations by the portable mill produces quickly followed, due to their strong reliance on the eco-forestry organizations for support.

The second challenge experienced by the six organizations was related to the quality and quantity of the lumber produced. The issue of lumber quality is likely related to the numerous portable mill producers involved. Invariably, each of these producers had varying degrees of training and experience, and the type and condition of portable sawmills was also likely to be highly variable throughout these operations. With these variations, a lack of consistency in the quality of the aggregate lumber is to be expected. Furthermore, the lumber produced by the eco-forestry operations was competing against lumber produced by industrial-scale sawmills utilizing modern processing technology and equipment. In the global marketplace, lumber is considered a commodity product and meeting standard moisture and grade specifications of the market is the minimum requirement for lumber producers to participate.

The low productivity of milling operations by communities can be attributed to a management model focused on portable sawmills with low production capacities in comparison to industrial-scale mills utilizing modern technology and equipment. The eco-forestry organizations pursued this approach because it was believed that increasing the number of portable mills in operation would eventually allow for economies of scale that would be competitive with other industry producers. The problem with this approach is the distance between each portable mill site and the inadequate road infrastructure in PNG severely limited the access for essential mill mechanical maintenance and facilitative support from the eco-forestry organizations. The Indigenous landowners received limited training in forest management, milling, lumber markets and business management, which created a strong reliance on the eco-forestry organizations for support. As the number of portable mill operations increased, this support became overextended and most of the portable mill producers subsequently failed to reach production targets or ceased altogether.

The final challenge identified in our analysis was the inability of the eco-forestry organizations to maintain FSC certification status. The primary factor identified as the cause for the lapses in certification was the inability or indifference of the Indigenous landowners in adhering to the FSC corrective action requests (Nerius et al., 2011). As FSC certification is the primary tool in PNG for evaluating the performance of sustainable forest management, it is implied that eco-forestry organizations failed in adhering to the principles that define eco-forestry. This begs the question; 'Is FSC certification the appropriate tool for evaluating the performance of Indigenous small-holder forestry in PNG?' Perhaps, third party certification as a sustainability evaluation tool is more appropriate for larger-scale forest management operations.

The challenges experienced by the eco-forestry organizations in achieving financial viability, lumber production quality and quantity, and an adherence to the eco-forestry principles highlight the failure of the eco-forestry approach to small-scale native forest management. The eco-forestry organizations were unable to develop the required capacities for a commercial operation. This includes the capacities of maintaining FSC certification, wood processing and business management. Even with substantial subsidization, the eco-forestry organizations were not always able to meet their management objectives. The ability to meet any of their management objectives ceased when their external funding concluded. Furthermore, they were not able to maintain adherence to the eco-forestry principles. Based on these findings, we conclude that this model for small-scale native forest management is not effective and it should not be scaled out to other communities in PNG.

5. Key themes emerging from the study, recommendations and conclusion

Our findings indicate that in PNG, the strategy of utilizing multiple portable sawmills to produce export oriented, FSC certified lumber, has failed. In contrast to earlier research findings by Hunt (2000), Fox et al. (2011) and Grigoriou (2011), our more recent evidence indicates that pursuing the international markets were not the best strategy for eco-forestry in PNG. Our analysis indicates that as a model of native forest management, eco-forestry is not financially viable in the long-term despite substantial financial subsidies. Listed below are the key themes that emerged from this analysis and our recommendations to assist in the development of future small-scale native forest management in PNG.

1) *The eco-forestry management model should re-focus to serve domestic markets.* This current model has been the primary approach supported by the PNG Government and NGOs operating in the country and our analysis has shown that this approach experienced significant challenges. Future operations for existing portable sawmills in PNG should focus on providing lumber for community development projects and, when appropriate, for local markets. It will be easier for future small-scale timber harvest operators to identify and meet the demands for local markets than international markets.
2) *Competency-based training is required for people who participate in future small-scale native timber harvests and processing should be developed prior to implementing commercial activities.* While most of the eco-forestry organizations provided sawmill and business training to the Indigenous landowners, the required capacities for commercial operations were never reached. We suggest that future small-scale commercial harvests utilize professionally trained portable sawmill operators that have already developed the necessary capacities required.
3) *Future small-scale native forest management timber harvests in PNG should conduct feasibility studies prior to management activities to filter out projects that are not financially viable.* Further research is needed to identify the methods and harvesting parameters for financially viable small-scale native forest management in PNG. We suggest

that this research involve collaboration with small/medium-scale private sector forest product businesses in PNG that have developed financially sustainable business models.

4) *FSC certification should be re-assessed in regard to its usefulness as a performance evaluation tool for small-scale native forest management in PNG.* This is not to say that small-scale forest managers should not strive to adhere to the FSC's sustainability principles as they are important guidelines for maintaining the integrity of forest ecosystems. Rather, it should be evaluated if FSC certification is an appropriate standard to apply to Indigenous landowners in PNG. Our analysis indicates that the FSC C&I may not be appropriate, given the land-use priorities and forest management capacities of Indigenous landowners in PNG.

This study found that utilizing portable sawmills to undertake small-scale native forest management (i.e. eco-forestry) in PNG has not been financially successful. All six of the eco-forestry organizations assessed in this study failed to achieve profitability and ultimately ceased all their eco-forestry operations. Even with substantial subsidies, lumber produced facilitated by these organizations did not meet the quality and quantity specifications of the buyers. Furthermore, the eco-forestry organizations struggled to maintain an adherence to principles that define eco-forestry. There is a need for a new small-scale native forest management model in PNG. Further research is required to identify a harvesting, processing and marketing model that incorporates collaboration with private sector businesses and professionally trained operators to achieve improved financial viability and adherence to forest management principles.'

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Appendix A. Supplementary data

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Identify alternative marketing models and develop financial programming models to evaluate performance of harvesting and marketing operations

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FST/2016/153 'Enabling Community Forestry in PNG'

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1 Introduction:

This report responds to project activity 3.6 ' Identify alternative marketing models and develop financial programming models to evaluate performance of harvesting and marketing operations. The intended methods for this activity were: 'Identify sawmills willing to participate in research. Once sawmills have been identified, multiple meetings will be held with management and staff in collaboration with TFTC to understand operational costs; including harvest setup, logging, hauling and milling. Information will also be collected on additional costs for undertaking Reduced Impact Logging (RIL) related techniques and implementing silvicultural treatments that favour growth of desired future crop trees. Financial modelling in Excel and Linear Programming (if appropriate) will be developed and used to assess options.'

Unfortunately, it was not possible to collect cost data related to RIL activities. All project travel to PNG ceased in early 2020 due to the Covid-19 pandemic. We had hoped that RIL cost data collection could be re-scheduled in 2021, and then again in 2022. Travel safety issues related to low vaccination rates in PNG have been the primary concern that has prevented this activity from occurring.

During the project mid-term review, one of the reviewers suggested that a forest finance workshop be implemented to introduce the PNG project partners to some of the financial analysis methods discussed in this report. This workshop was conducted in April 2022. A workshop report is in Appendix 47.

2 Methods:

2.1 Discounted cash flow analysis of portable sawmill operations:

The DCF analysis of portable sawmill operations utilized a mixed-methods approach. Key informants were interviewed from an eco-forestry NGO in Madang, from forest product businesses in Madang, and from staff at the Timber and Forestry Training College (TFTC). The data collected from the interviews was placed into a DCF model using Microsoft Excel software and Monte Carlo risk analysis simulation techniques. The detailed methods of this assessment are presented in Scudder et al. (2019b), which is in Appendix 45.

2.2 Small-scale wood product value adding opportunities analysis:

An analysis on value adding opportunities was undertaken to identify potential options for improving the low financial returns expected from milling rough-sawn lumber with portable sawmills. For this investigation, we conducted a production cost analysis of value-add wood products. The detailed methods of this assessment are presented in section 2.2 of the report for project activity 3.7, titled, ‘Value Adding Opportunities for Community Timber in Local Sawmills in Lae.’ This report is in Appendix 49.

2.3 Assessment of small-scale forestry informal market:

A case study was conducted on small-scale forestry informal markets within the Morobe Province. The detailed methods of this case study are presented in Scudder et al. (2019a), which is in Appendix 37.

3 Results:

3.1 Financial analysis of portable sawmill operations:

The research results revealed that using portable sawmills to produce rough-sawn lumber is highly unlikely to be financially viable if an even distribution of the trees at the harvest site were milled. The variable processing costs of portable sawmills are very high relative to the average sales prices of rough-sawn lumber. During the analysis, it was discovered that only a small selection of timber species had per unit sales prices that were greater than the per unit production costs. This finding illustrated that the species composition of the harvest site was a critical factor for achieving financial viability. The high level of species diversity of PNG’s forests emphasized the importance of harvest site selection. Harvest site selection was also affected by the distance to market due to high lumber transportation costs.

The research also discovered that maximizing daily log input and A grade lumber recovery were also critical factors for achieving financial viability with portable sawmills. The advent of a desired timber species composition at the harvest site did not guarantee financial viability. This finding highlighted the importance of competency-based training for small-scale timber harvests and portable mill operations.

We concluded that the financial viability of portable sawmill operations could be greatly improved if further value was added to the rough-sawn lumber.

3.2 Small-scale wood product value adding opportunities:

We determined that the value-add wood products that offered the best potential opportunities are T&G wood flooring (made from *Pometia pinnata*, and *Intsia bijuga*), weatherboard (made from mixed softwoods, and architrave made from mixed hardwoods. We found that these products had the largest profit margins and require a larger volume of use per housing unit relative to D-mould. Structural lumber products that are in demand should still be produced, but we recommend that the cutting patterns for milling the logs focus on producing flooring, weatherboard, and architrave pieces. In addition, focus on these value-add products can act as a hedge against the larger sawmills that are able to produce rough-sawn lumber products at lower costs.

We suggest that value-add wood product manufacturers strive to produce the highest quality T&G flooring and weatherboard within the target market. Opportunities for improving product quality can be achieved with the purchase of modern machining equipment, improved drying and grading standards, and improved chemical treatment procedures. We recommend that further research be conducted to identify the specific product attributes desired by the target market related to these quality improvement opportunities. We also recommend that further research be conducted to identify the service attributes desired by the target market. Some examples of service attributes are; installation instructions included with the product; installation training; product delivery; prices; payment options; and sales reps being available.

In addition to the products suggested above, we also suggest that further research be conducted into identifying additional market opportunities for the wood product residues/waste materials. One product option that has been identified for the short-length timbers/offcut materials is foldable, portable and do-it-yourself (DIY) furniture such as student desks small tables and stools (Ozarska et al. 2019). Research by Ozarska et al. (2019), in collaboration with TFTC, completed a DIY furniture pilot project utilizing previously unwanted short-length timbers. Further research should be conducted on the potential market opportunities for these products. Firewood is an additional product that has been identified as an option for utilizing the wood slabs, and lumber offcuts (Yakuma 2017). The residue product options for sawdust and shavings produced by the moulding machine and planer/thicknesser should also be explored. These residues could potentially be used for charcoal production and/or sold to charcoal producers. By identifying product lines for these wood residues, additional revenue streams can be achieved, and wood product waste can be reduced.

3.3 Assessment of small-scale forestry informal market:

The informal market case study found that FROs sold their timber to informal sector operators for immediate cash needs. Small-scale wood product manufacturers operating in the informal sector have captured most of the value of the harvested timber relative to the FROs and portable sawmill operators that only produced rough-sawn lumber. Most of the portable saw millers had not been able to acquire the financing necessary to purchase equipment that would have allowed them to process the products beyond rough-sawn lumber. One of the factors that hindered the financing of these operators is the illegal nature of the informal sector.

4 Conclusion:

We found that using portable sawmills in tropical forests can be financially viable if trained operators are used and only high-value timber species is harvested and milled. However, only a small selection of timber species was determined to be financially viable and tropical forests have a high level of timber species diversity. If saw millers continue to only harvest these species, it is likely that the forest will continue to be high-graded until all the accessible high-value trees have been removed. The research found that this challenge could be mitigated if the portable saw millers harvested additional lesser-known species and further processed the rough-sawn lumber to produce products with higher value. Most of the saw millers operate within the informal sector, which is not technically legal and impedes their ability to access financing. Revisions to the existing forest policy harvest permits that allow these saw millers to become legal operators could mitigate the financing challenge. Revising forest policies to improve the timber royalty rates could increase the portion of timber revenues collected by the FROs. We concluded that making these changes would be the best market model approach for small-scale wood product manufacturing within the study site.

References:

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Are portable sawmills a financially viable option for economic development in tropical forests?

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ABSTRACT

Community forest enterprises facilitated by non-governmental organizations (NGOs), using portable sawmills to produce rough-sawn lumber is one approach being pursued by tropical forest indigenous communities to improve their livelihoods. To investigate the profitability of portable sawmills operated by community forest enterprises, we developed a discounted cash flow model with a Monte Carlo risk analysis simulation. We populated this model using forest inventory data from six forest sites in Papua New Guinea, combined with cost and revenue data collected in country. We found that the application of this small-scale native forest management model has a high likelihood of producing a negative net present value (NPV). The cash outflows to produce the lumber are found to be consistently greater than the cash inflows from lumber sales, resulting in a probability of achieving a positive NPV of 0.04. If only the most valuable species are harvested the probability of achieving a positive NPV increased to 0.56. However, the communities would be at risk of overexploiting or high-grading their forests. We recommend that future community forestry projects utilizing portable sawmills explore value adding opportunities for rough-sawn lumber to overcome the high costs of portable sawmill operations and reduce the potential occurrence of forest high-grading.

1. Introduction

During the last few decades there has been increased international attention to reducing global deforestation by transitioning forest management, including harvesting, to indigenous communities (White and Martin, 2002). Community-based forestry (CBF) emerged in the 1970s and 1980s as an alternative to industrial forestry that characterized forest management in much of the global south during the colonial and early post-colonial periods (Gilmour et al., 1989). There are approximately 60 million indigenous people living within the world's tropical forests, with an additional 400 to 500 million people that are directly dependent on tropical forest resources for their livelihoods (White and Martin, 2002). In many countries, CBF began with a focus on providing subsistence goods to communities and has since transitioned to a greater focus on commercial forest products (Gilmour, 2016). A key challenge of CBF management is identifying commercialization strategies that will enable communities to realize the full economic benefits of their forests (Gilmour, 2016). The use of portable sawmills to mill rough-sawn lumber is one commercialization strategy that has been adopted by Community Forest Enterprises (CFEs) in many tropical forest countries (Kilkki, 1992; Chatterton et al., 2000; Macqueen, 2008; Humphries et al., 2012). The capital requirements and operational training required for portable sawmills is low, relative to fixed-site sawmills, which is one factor that helps CFEs to participate in commercial lumber markets. CFEs that successfully market their timber and non-timber products can increase the financial capital entering their communities relative to communities that only use their forests for subsistence. The additional financial capital can be used for acquiring essential goods and services, which can support community economic development.

Despite the extensive implementation of CBF throughout tropical forests, there have been few studies that have evaluated the effectiveness of CFEs (Charnley and Poe, 2007). Specifically, there have been few studies conducted on the changes of community financial capital resulting from CFE portable sawmill activities. Failing to assess the financial viability of these CFEs makes it difficult to determine if using portable sawmills is a financially viable option that should be pursued for small-scale native forest management by forest-dependent indigenous communities. To address this gap in the literature, we assessed the operational model of CFEs using portable sawmills for commercial activities in PNG.

In PNG, there are approximately 29 million hectares of forest with 97% of the forest held under customary land ownership by indigenous clan groups (PNGFA, 2009). Portable sawmills were initially imported

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into PNG in the 1970s, by church groups and NGOs to provide indigenous communities with the means to mill lumber for their own needs. Advances in the design of these mills in the 1980s improved portability, resulting in widespread adoption of portable sawmills throughout the country (Bun and Scheyvens, 2007). It is estimated that there are approximately 2000 portable sawmills in PNG that are operational as of 2016 (Jenkin, 2016). Beginning in the 1990s, multiple NGOs began supporting CFEs by providing timber felling and mill operation training. The lumber milled by each CFE was transported to small lumber yards operated by the NGOs or private businesses that aggregated the lumber and facilitated sales to domestic and international markets. It was found that by 2010 all the NGOs had ceased their lumber export operations, which resulted in the cessation of CFEs affiliated with the NGOs as well (Scudder, 2017). This suggests that the business model under which these CFEs operated was flawed.

Previous financial assessments of portable sawmilling in PNG found that this can be financially viable if production targets are achieved (Chatterton et al. (2000), Hunt (2000) and Grigoriou (2011). However, none of these analyses included costs of NGO facilitation and of operating associated small-scale lumber yards. These expenses would normally be included in a 'total cost accounting' evaluation of the forest management model. The absence of a total cost accounting is a study limitation that has been identified in multiple other portable sawmill CFE financial analyses conducted in other tropical countries (Humphries et al., 2012). To address this research gap, we conducted a financial analysis of the profitability of portable sawmill CFEs. The analysis incorporated a total cost accounting approach. We modelled NGO-facilitated portable sawmill operations and small-scale lumberyards to estimate the expected operational costs and revenues. The results of this modelling are used to analyse the potential of portable sawmills operating under this forest management model. In the next section of this paper, we discuss the methods we used to undertake the analysis. In the following section, we present our results and finally, we present our key findings and provide recommendations for future CFEs.

2. Research method

2.1. Data collection

Data were collected from interviews with key informants in the cities of Lae and Madang in PNG during three trips in 2016 and 2017. An interview protocol was designed to identify the activities and associated costs of the NGO facilitation process, portable sawmill operations, small-scale lumberyard operations, and the prices received in domestic and international lumber sales. All the interviews were conducted by the first author with hand written notes taken. The initial interviews were with four current and former employees of one of the CFE NGOs, the Foundation for People and Community Development (FPCD). The purpose of the FPCD interviews was to identify the activities and associated costs of the NGO facilitation process, portable sawmill operations, and small-scale lumberyard operations. The second round of interviews was with representatives of three forest product businesses in the city of Madang. The purpose of these interviews was to ascertain the domestic prices being received for milled lumber according to tree species milled. The third round of interviews was with two employees from the Timber and Forestry Training College (TFTC) in the city of Lae. The purpose of these interviews was to identify capital equipment costs for new and used equipment and the annual maintenance costs for the equipment.

2.2. Developing the financial model

We conducted a discounted cash flow (DCF) analysis to estimate the net present value (NPV) of cash flows generated by portable sawmill CFEs facilitated by an NGO in PNG. In developing the model, we followed the principles of capital budgeting of investment projects set out in Dayanandra et al. (2002) and Harrison and Herbohn (2017). We categorized model variables as being capital flows and operational flows (Table 1). A five-year time horizon was selected for the DCF analysis based on the life expectancy of the capital equipment, which was assumed to never exceed five years due to the harsh operating conditions in PNG. The discount rate selected for the DCF model was 10.5%,[1] which is the current yield of long-term (5.5 year loan duration) debt financing issued by the Bank of PNG on behalf of the PNG government (BPNG, 2018). All the monetary variables incorporated in the DCF model were converted to 2017 USD currency equivalents using consumer price indices and foreign exchange rates collected from the Bank of Papua New Guinea (BPNG, 2018), and the Reserve Bank of Australia (RBA, 2018).

Table 1
Financial model cash flow variables.

Cash flow categories	Cash flow variables	
	Cash inflows	Cash outflows
Capital flows	Salvage value	Capital outlay
Operational flows	Lumber revenue	Portable sawmill operations
		Portable sawmill labour
		Lumber transport lumberyard
		Lumber export shipping
		NGO overhead
		NGO labour
		NGO business licences & harvest permit
		Forest Stewardship Council (FSC) certification
		Taxes

The DCF model was constructed in Excel. Monte Carlo risk analysis simulation was used to account for uncertainty associated with key variables. We used '@RISK' software for the Monte Carlo risk analysis simulation, which is a Microsoft Excel Add-in software program produced by the Palisade Corporation. The risk analysis simulation followed methods outlined by Winston (2008) in which all cash flow variables determined to have values with inherent uncertainty were assigned normal or triangular distributions. The variables assigned a normal distribution had a mean value based on our data collection and were assigned a standard deviation of that mean value. The variables assigned a triangular distribution were given minimum, most likely and maximum values. The DCF model was designed to randomly select a value within the assigned distribution range of each uncertain variable for each iteration of the simulation. The number of iterations selected for the Monte Carlo risk simulation was 100,000.

2.3. Capital and operating cash flow variables

2.3.1. Cash flow variables for capital outlays

The key informants from FPCD determined that the required capital equipment for portable sawmill operations would be two portable sawmills, two chain saws, two winches, a tractor/skidder and a truck (Table 2). The portable mill model selected was an 8" Lucas mill 200 mm × 200 mm. The chainsaw model selected was a Stihl AV 072. The winch model selected was a Tugger 3 ton. The tractor/skidder model selected was a Massey Ferguson Dyna 4, 5455 Series 92 HP. The truck model selected was a Hino FT/GT 500 Series w/20' Steel Tray. Additional required equipment for NGO facilitation activities were a computer, printer, and office furniture. All the capital equipment was estimated to have a life expectancy of 5 years. All the capital equipment was estimated to have a salvage value of 10% of the purchase price.

[1] The high yield rate of BPNG's long-term debt financing (10.5%) reflects the high degree of risk associated with conducting business in PNG.

Table 2
Assumed probability distributions of uncertain cash flow variables for capital outlays (2017 USD).

Capital equipment items	Form of distribution	Min.	Mean	Max.
Portable Mill (8″ Lucas Mill 200 mm × 200 mm)	Triangular	$19,672	$20,033	$20,395
Stihl AV 072 chainsaw and accessories	Triangular	$2399	$2745	$3091
Tugger winch (3 ton)	Triangular	$1037	$1404	$1755
Truck (Hino FT/GT 500 Series w/20′ Steel Tray)	Triangular	$72,000	$85,000	$100,000
Tractor (Massey Ferguson Dyna 4, 5455 Series 92 HP)	Triangular	$40,236	$53,649	$67,061
Computer/Printer/Office Furniture	Triangular	$800	$1000	$1200

2.3.2. Merchantable log species distribution

Log species percentage distributions were calculated based on FPCD forest inventories and forest management plans for six sites in the Madang Province (FPCD, 2005; 2006a; 2006b; 2006c; 2007, and 2011). The log species were separated into nine categories, eight represented individual species and one was an aggregate of all remaining species (mixed hardwoods). Only the eight individual species were exported to international markets. These nine categories were selected based on the domestic and export markets price categories for PNG lumber. All the mixed hardwoods were sold to domestic markets in PNG. These price categories were identified from interviews with key informants and from Subendranathan (2008) and Grigoriou (2011). The DCF model was designed to randomly select a species distribution from one of the six sites for each iteration of the model simulation. The model assumes that all milled lumber is evenly distributed between the species that exist on each site for the duration of the five-year time horizon. The even distribution by species was chosen to reflect the harvest designs discussed in the forest management plans produced by FPCD. The objectives of these management plans were to conduct harvests that did not alter the species composition and structure of the forest, or transform the forest to an earlier successional stage.

2.3.3. NGO management activities

The interviews with the key informants from FPCD determined how the NGO management process would be modelled for this study. The NGO activities required four employees; a manger, an administrative assistant/driver, and two foresters. NGO management activities included the purchase of all required licences, permits, and capital equipment. In year zero, the NGO was modelled to conduct a forest inventory, develop a forest management plan, provide sawmill training to the FROs and initiate Forest Stewardship Council (FSC) sustainability certification. In years one through five, the NGO and CFEs were modelled to conduct timber harvesting, milling, and transport of the lumber to a lumberyard. For the harvest and milling operations, we modelled the use of two portable sawmills and one tractor for log skidding/snigging, which all operated simultaneously. The interviews with key informants from FPCD revealed that two portable sawmills were the maximum number of mills that four NGO employees could effectively manage.

2.3.4. Portable sawmill operation parameters

Three critical parameters were identified by key informants for the portable sawmill operations; annual days of operation, daily log throughput, and rate of recovery of sawn timber. For this study, we used a triangular distribution for annual days of operation with a value range of 100 (Minimum), 200 (Most likely) and 250 (Maximum). The maximum possible days of annual operation were based on a five-day work week with two weeks of holiday leave. The most likely days of operation range were chosen to reflect two months of likely inoperable periods due to the wet season. The annual days of operation for the two portable sawmills were determined to be positively correlated and assigned a correlation coefficient of 0.7. The daily log throughput of individual sawmills was modelled with a triangular distribution with values ranging from 1 m^3 (minimum), 5 m^3 (most likely) and 6 m^3 (maximum).

For this study, we used a rate of recovery of the sawn timber that was between 35% and 50% to reflect the variation in skill among mill operators. Interviews with key informants revealed that recovery is separated between ‘A grade’, ‘B grade’, and ‘C grade lumber’. The A grade lumber was defined by the key informants as being of higher quality than the B grade due to reduced imperfections such as knots, wane, checking, or warping and cupping of the lumber. The B grade lumber could be sold in domestic markets, but only the A grade could be exported. The C grade lumber has no market value and was used internally by the CFEs or discarded. The selected lumber recovery percentage for each lumber grade was based on a report by Nerius et al. (2011) and interviews with key informants. We used a triangular distribution for lumber recovery with total recovery values being between 35% (Minimum), 45% (Most likely) and 50% (Maximum).

The portable sawmill operational costs identified by key informants were CFE labour, mill fuel, mill oil, chainsaw oil and fuel, tractor fuel, annual mill maintenance, and annual tractor maintenance. The labour requirements for portable sawmill operations were determined to be two trained mill operators and four assistants for each portable sawmill. It was determined that the CFE labour would be sourced from the community where the timber harvests were occurring.

2.3.5. Lumber transport and lumberyard sales

A public motor vehicle (PMV) was modelled for transporting the lumber from the harvest site to the lumberyard. The PMVs are capable of transporting approximately 6 m^3 per trip. PMV prices were collected from interviews with key informants. Shipping costs for the exported lumber were collected from key informants based on previous export shipments.

2.3.6. Cash inflows from lumber sales

Lumber prices by species for the exported A grade lumber were based on previous prices paid by an Australian buyer, collected from Subendranathan (2008) and Grigoriou (2011).[2] These values were inflated to 2017 USD values using consumer price indices and foreign exchange rates collected from the Reserve Bank of Australia (RBA, 2018). The domestic lumber sales were comprised of A grade mixed hardwoods lumber and B grade lumber of all species groups. The prices for domestic lumber sales were collected during interviews with key informants. A weighted average lumber price was generated for A grade and B grade lumber for each forest inventory site using species distribution percentages and the prices discussed above. We assigned a normal distribution to the weighted average lumber prices for each site with a standard deviation of 8.4% of the weighted average price. The standard deviation was chosen based on the standard deviation of Australian tropical lumber import prices for years 2012 to 2016, which was collected from ITTO (2017). The weighted average prices for A

[2] At the time of this study, all exports to Australia had ceased making it impossible to identify a current market price. The Australian buyer was not able to comment on what the potential current price would be.

Table 3
Cash flow variables for operating activities (2017 USD).

Merchantable log species distribution by site						
Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Celtis spp.	6%	21%	4%	8%	4%	8%
Dracontomelon dao	5%	3%	3%	0%	3%	2%
Instia bijuga	21%	2%	19%	14%	2%	0%
Pometia pinnata	5%	34%	15%	11%	7%	75%
Pterocarpus indicus	4%	0%	0%	2%	0%	0%
Terminalia spp.	0%	3%	16%	8%	3%	1%
Toona soreni	0%	0%	5%	0%	4%	2%
Vitex cofassus	0%	0%	9%	1%	0%	6%
Mixed Hardwoods	59%	37%	29%	55%	78%	7%

NGO annual operation expenses (Certain values)	
Labour	$43,462
Harvest setup and facilitation supplies per mill per day	$30
Vehicle maintenance (% of purchase)	7%
Office rent	$13,079
Internet & phone credit	$2616
Utilities	$4360
Office supplies	$1308
Marketing	$2906
Post Office Box	$181
Business registration[a]	$84
Forest industry participant license[a]	$184
Timber Authority performance bond[b]	$6286
FSC certification year 1	$10,031
FSC certification year 2	$4360
FSC certification every following year	$2348

NGO annual operation expenses (Uncertain values)

	Distribution	Mean	SD
Vehicle fuel	Normal	$1743	$350

Portable mill operation parameters (Uncertain values)

	Distribution	Min.	Mean	Max.
Annual days of sawmill operation	Triangular	100	200	250
Daily m^3 log input of sawmill	Triangular	1	4.5	6
A grade lumber recovery	Triangular	18%	24%	27%
B grade lumber recovery	Triangular	14%	16%	18%
Mill fuel per m^3 of log input	Triangular	$10	$13	$17
Mill oil per m^3 of log input	Triangular	$0.68	$1.04	$2.07
Chainsaw fuel/oil per day	Triangular	$5	$6	$7
Tractor fuel per m^3 of log input	Triangular	$14	$15	$17
Portable mill labour (Daily)	Triangular	$90	$100	$110
Lumber transportation to lumberyard per m^3	Triangular	$72	$80	$88
Annual mill maintenance (% of purchase)	Triangular	27%	30%	33%
Annual tractor maintenance (% of purchase)	Triangular	10%	15%	20%

Revenue from lumber sales (Uncertain values with normal distribution)

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Weighted average A grade price (Mean)	$482	$441	$472	$419	$327	$585
(SD)	$40	$37	$40	$35	$27	$49
Weighted average B grade price (Mean)	$156	$185	$196	$161	$130	$226
(SD)	$13	$16	$16	$17	$11	$19

Annual Inflation (Uncertain values)

	Distribution	Min.	Mean	Max.
Australian inflation	Triangular	1.3%	1.9%	2.5%
PNG inflation	Triangular	4.6%	5.5%	6.7%
Interest on long-term debt (Certain value)				
Annual percentage rate	10.5%			

(*continued on next page*)

Table 3 (*continued*)

Taxes (Certain values)	
Income range	Tax rate
$0 - $2200	0%
$2201 - $5657	22%
$5658 - $10,372	30%
$10,373 - $22,001	35%
$22,002 - $78,575	40%
$78,576 - No limit	42%

[a] Paid once in year zero.
[b] The performance bond is cash paid in year zero and a cash received in year ten.

Table 4
Sales prices by species per m^3 (2017 USD).

Species	A grade	B grade
Dracondomelon dao	$833	$235
Instia bijuga	$910	$235
Pometia pinnata	$666	$235
Pterocarpus indicus	$958	$235

grade and B grade lumber were determined to be positively correlated and assigned a correlation coefficient of 0.9.

2.3.7. Annual inflation rate

All the monetary variables were initially based on current price data. We designed the model to reflect annual growth in lumber revenues and operational costs caused by inflation. For each year of the DCF model, an inflation percentage was generated for Australia and PNG. These inflation values were generated from minimum, average, and maximum inflation values during the last five years as reported by the Reserve Bank of Australia (RBA, 2018) and the Bank of Papua New Guinea (BPNG, 2018).

2.3.8. Depreciation and taxes

For this analysis, we depreciated all the capital purchases using the straight-line depreciation method. This was done to calculate the taxable income after subtracting depreciation. It was assumed that all taxes would be paid by the CFE forest landowner. CFEs in PNG can range from a single family to an entire community. The model assumes a single family owns the land being harvested. Tax outflows were based on PNG's progressive tax bracket system with tax rates collected from the PNG Internal Revenue Commission (IRC, 2018). After calculating taxable income and net income after tax, our model adds back the depreciation expenses to calculate the after-tax net operating cash flow (Table 3).

2.4. Data analysis

During the data analysis, we found that only four of the tree species *(Dracontomelon dao*, *Intsia bijuga*, *Pometia pinnata* and *Pterocarpis indicus)* had a sales value per m^3 that was greater than the mean cost of milling per m^3 (i.e. cash outflows from sawmill operations and sawmill labour). The interviews with key informants revealed existence of an informal sector of portable mill operators that primarily harvest these species due to the high sales prices. This equates to essentially high-grading the forest. Little is known about this sector, because the PNG government does not have the resources to track or regulate it. We decided to compare the effect high-grading the forest to the results of our original DCF model that assumed a harvest composition uniformly distributed across species. To do this, we changed the harvest percentages to 25% for each of the four species mentioned above. The sales prices for these species are presented in Table 4. All the other variables were unchanged. In the results, we refer to our original model as 'Model 1' and the high-grading model as 'Model 2.'

Descriptive statistics (Mean, minimum, maximum, median, mode, and standard deviation) were determined for the sawmill productivity variables and the NPV values produced from the Monte Carlo simulation of both models. An NPV probability distribution curve was created for both models. A sensitivity analysis was conducted of the model variables with inherent uncertainty to identify the variables that were most likely to affect the mean NPV. The sensitivity analysis is a report function of the @Risk software that determines the impact that each input variable will have on the range of values for a selected output. We also conducted an additional sensitivity analysis on the discount rate. The discount rate was increased and decreased by 30% to assess the changes to mean NPV for both models. These discount rates were 7.35% and 13.65%.

3. Results

3.1. Lumber production

Table 5 presents the descriptive statistics for productivity variables of each mill. The total mean annual lumber production estimated by our model was 572 m^3 or 286 m^3 per mill. The lumber production results were the same for both mills in both models.

3.2. NPV and mean cash flow assessment

In Model 1, the mean NPV was -$7,005,352,017 USD (Table 6). This was due to the net cash flows being negative for every year of the operation (Table 7). The mean cash inflows from lumber sales were always less than the mean cash outflows for operating activities. As a

Table 5
Descriptive statistics of sawmill productivity.

Productivity variables	Mean	Minimum	Maximum	Median	Mode	Standard deviation
Days of operation	183	100	250	187	200	31
Daily log input	4 m^3	1 m^3	6 m^3	4 m^3	5 m^3	1 m^3
Lumber recovery	43%	36%	49%	43%	44%	2%
A grade lumber production	169 m^3	26 m^3	370 m^3	168 m^3	171 m^3	56 m^3
B grade lumber production	117 m^3	19 m^3	247 m^3	117 m^3	106 m^3	38 m^3

Table 6
Descriptive statistics for NPV of Models 1 and 2 (Thousands 2017 USD).

Model	Mean	Minimum	Maximum	Median	Mode	Standard deviation
Model 1 (Even distribution harvest)	−700.5	−1300.0	278.7	−747.8	−809.1	235.7
Model 2 (High-grading)	24.0	−638.7	710.7	29.0	−88.4	200.4

Table 7
Mean cash flows of Model 1 (Thousands 2017 USD).

Year	0	1	2	3	4	5
Capital flows						
Capital outlay	−188.7					
Salvage value						18.9
Operating flows						
Lumber sales		136.2	140.2	144.3	148.4	152.5
Portable sawmill operations		−62.7	−66.1	−69.4	−72.7	−76.0
Portable sawmill labour		−38.7	−40.8	−42.8	−44.9	−46.9
Lumber transport lumberyard		−48.3	−50.9	−53.4	−56.0	−58.6
Lumber export shipping		−4.1	−4.3	−4.6	−4.8	−5.0
NGO overhead	−32.7	−34.0	−35.8	−37.6	−39.4	−41.2
NGO labour	−43.5	−45.9	−48.3	−50.8	−53.2	−55.6
NGO business licences & harvest permit	−6.6					6.2
FSC certification	−10.0	−4.6	−2.6	−2.7	−2.9	−3.0
Taxes		−0.4	−0.4	−0.3	−0.3	−0.3
Net cash flow	−281.5	−102.6	−108.9	−117.3	−125.7	−109.0

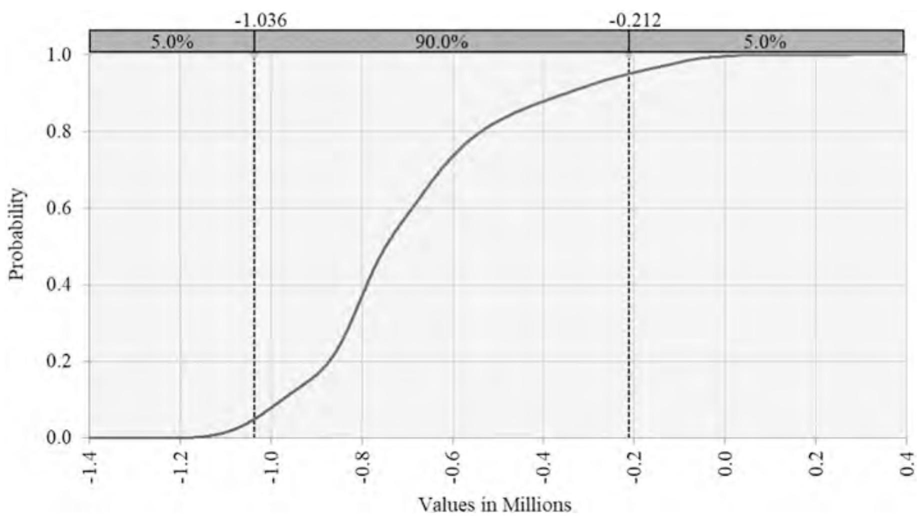

Fig. 1. NPV probability distribution curve of Model 1.

result, the probability of achieving positive NPV was 0.04 (Fig. 1). The variables that had the greatest impact on the mean NPV for Model 1were; (1) daily log input of the sawmills; (2) the percentage of A grade lumber recovery; and (3) the weighted average A grade and B grade lumber prices for site 6. The first two variables were related to sawmill productivity and determined how much A grade lumber was produced daily. Site 6 had a weighted average price per m^3 of A grade lumber that was $104 to $258 (2017 USD) higher than the other five sites. This higher weighted average price was due to the site being comprised of 75% *Pometia pinnata*, which had a specific price of approximately $666 (2017 USD) per m^3 of lumber.

The operational activities that resulted in the highest cash outflows were related to the portable sawmill production. Portable sawmill operations and portable sawmill labour together, represented 43% of mean total operational cash outflows. The mean cash outflows for NGO facilitation (NGO overhead and labour) represented 34% percent of mean total operational cash outflows. This amount represents the expected cost of an NGO to facilitate the CFE operations. When the cash outflows for NGO activities was removed to represent subsidized funding for the NGO, the mean total net cash flow values for operating activities remained negative. Cost of transport of lumber to the lumberyard also comprised a substantial percentage of cash outflows, being 20% of mean total cash outflows. This reflects the high costs of shipping/transportation in PNG due to poor road infrastructure. The remaining operational cash outflows were approximately 3% of mean total cash outflows.

In Model 2, the mean NPV was $240,232,017 USD. The mean net cash flows were positive during years one through five (Table 8). As a result, the probability of achieving a positive NPV was 0.56 (Fig. 2). The variables that had the greatest impact on the mean NPV of Model

Table 8
Mean cash flows of Model 2 (Thousands 2017 USD).

Year	0	1	2	3	4	5
Capital flows						
Capital outlay	−188.7					
Salvage value						18.9
Operating flows						
Lumber sales		350.5	362.0	373.5	384.9	396.4
Portable sawmill operations		−62.7	−66.1	−69.4	−72.7	−76.0
Portable sawmill labour		−38.7	−40.8	−42.8	−44.9	−46.9
Lumber transport lumberyard		−48.3	−50.9	−53.4	−56.0	−58.6
Lumber export shipping		−8.1	−8.5	−8.9	−9.4	−9.8
NGO overhead	−32.7	−34.0	−35.8	−37.6	−39.4	−41.2
NGO labour	−43.5	−45.9	−48.3	−50.8	−53.2	−55.6
NGO business licences & harvest permit	−6.6					6.2
FSC certification	−10.0	−4.6	−2.6	−2.7	−2.8	−3.0
Taxes		−29.4	−29.8	−29.6	−29.4	−31.0
Net cash flow	−281.5	78.7	79.1	78.1	77.0	99.2

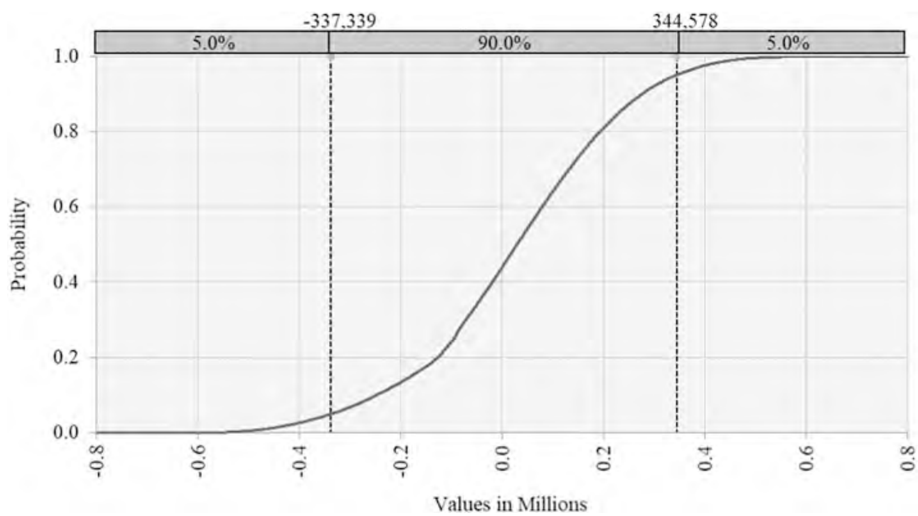

Fig. 2. NPV probability distribution curve of Model 2.

2 were; (1) daily log input of the sawmills; (2) annual days of operation; and (3) and the percentage of A grade lumber recovery. This differed from the Model 1 results because the annual days of operations was not a variable that had a profound impact on mean NPV of Model 1. The reason for this is that the sawmill production costs (operations & labour) of Model 1 were much higher relative to lumber revenue cash inflows. Operating less days during the year did not have as great of an impact on mean NPV as the amount of A grade lumber produced on the days that the mills did operate. The operational cash outflows were similar to Model 1, with the difference being increased export shipping cash outflows and increased tax cash outflows. These changes were due to the species harvested having a larger international market volume than Model 1 and larger taxable revenues. The four species used in Model 2 were exported to international markets. The 'Mixed hardwood' species in Model 1 were only marketed domestically.

Our sensitivity analysis of the discount rate revealed that increasing or decreasing the discount rate by 30% did not result in Model 1 achieving a positive mean NPV. The higher discount rate of 13.65% resulted in Model 1 receiving a less-negative mean NPV than the lower discount rate of 7.35% because the cash flow losses had been further discounted. In Model 2, the reduced discount rate of 7.35% increased the mean NPV to $510202017 USD. When the discount rate was increased to 13.65% the mean NPV of Model 2 decreased to $6862017 USD. Descriptive statistics of this sensitivity analysis are provided in Table 9, located in the appendix.

4. Discussion

We found that CFEs using portable sawmills to produce rough-sawn lumber for export from an even distribution of the tree species found at the harvest site are highly unlikely to be financially viable. The characteristics of the forest being harvested has a major impact on profitability. Our study was unique in that we used actual data from six community forests, whereas all past studies have not accounted for this as a factor affecting profitability of portable sawmills. Only four of the tree species *(Dracontomelon dao*, *Intsia bijuga*, *Pometia pinnata* and *Pterocarpis indicus)* had a sales value per m^3 that was greater than the mean cost of milling per m^3 (i.e. cash outflows from sawmill operations and sawmill labour). This indicates that the variable processing costs are very high and/or the sales prices are low and as a result, the variable costs are not being covered. As such, the species composition of the forest stand plays an important role in determining the financial viability of CFEs. Not all forests will be able to support CFE operations and the nature of the forest resource available is an important consideration in assessing whether CFEs are a viable option. These findings illustrate that not all forest sites will be suitable for sawn timber production. In addition, difficult site terrain and long distances to markets can negatively impact on the suitability of a forest area for CFEs.

If CFEs only harvest a small selection of species which produce positive gross margins as was done in Model 2, the probability of achieving financial viability is greatly improved. However, this may result in 'high grading' of the forest, with the resulting negative impacts on sustainability and biodiversity conservation. Our interviews with key informants revealed that *Intsia bijuga* is the most sought-after timber species in PNG. Its primary uses are for house posts, beams, structural lumber and furniture. The popularity of this species is due to extremely dense heartwood (641–961 kg/m3), limited shrinkage insect repellent properties, and the rich dark colour of the heartwood (Thaman et al., 2006). Due to its high popularity, *Intsia bijuga* has been recognized as being seriously threated from overexploitation in the South Pacific (Thaman et al., 2006). This species is also a shade-tolerant and slow growing species that can take 75 to 80 years to reach maturity (Thaman et al., 2006). If this species continues to be over-harvested in PNG, it is likely to be replaced by less valuable early successional pioneer species. Research by Louman (1996), identified that many of the portable sawmill owners in PNG select the species and quantity of trees to be cut in response to market demand rather than following a prepared management plan. If CFEs only harvest the most valuable species and do so at an unsustainable level, it is likely that future members of these communities will inherit forests with a reduced commercial value.

The volume of lumber produced by the sawmill per year had a substantial impact on financial viability. The main variables affecting volume of lumber produced in Model 1 were daily log input, and A grade lumber recovery. This finding is corroborated by research on portable sawmill operations in northern Queensland, Australia, which found that short-run average cost curves were highly responsive to daily log throughput and the rate of lumber recovery (see Smorfitt et al., 2006). Lumber productivity also had a substantial impact on the financial viability of Model 2. Despite only harvesting the four most valuable species, 44% of the model iterations resulted in a negative NPV. This indicates that selectively harvesting the most valuable species will not guarantee profitability. Typically, CFEs employ members of local communities, who have little or no training in sawmilling operations. This contributes to low levels of efficiency compared to commercial sawmilling operations, including low rates of throughput and low recovery rates, especially for A grade lumber. Other socio-cultural issues may also negatively impact of CFE operations. Many rural communities in PNG are transitioning from subsistence agriculture to a cash-economy and have an embedded culture of reciprocal trade and wealth sharing between families, clans, and communities (Kaitilla, 1995; Jacobsen, 1997; Gesch, 2007). Interviews with FPCD employees revealed that the concept of investing profits back into the CFE business for maintenance and consumables was difficult for many communities to comprehend. An expression that was commonly heard by the FPCD employees from members of the CFEs was, 'the strangeness of business thinking.' Training and capacity building is an essential requirement for the successful operation of CFEs.

Our study clearly suggests that a new model for sustainable forest management is required for CFEs. The model of harvesting timber evenly between species present at the site and using portable sawmills to produce rough-sawn lumber for export is not financially viable. The variable processing costs per unit of lumber are prohibitively high relative to the sales prices per unit received. Overcoming the high costs of portable sawmill operations and improving potential profitability will require further research into value-add opportunities for country-specific species and associated markets. Further research will also be required to see if adding additional value to lesser-value tree species will result in a profitable outcome, thus reducing the potential occurrence of high-grading. We also recommend that supporting organizations assess the operational and business management capacities prior to implementing commercial activities. Contracting out some or all the CFE activities to professionally trained operators until CFEs have developed the necessary capacities is a strategy that other CFEs have pursued (Macqueen, 2008). The process of adding additional value to rough-sawn lumber presents an additional requirement for capacity development that may or may not be appropriate for indigenous CFEs. A case-by-case implementation decision process will be required.

To determine if the conditions in PNG are unique or comparable to other areas, we compared PNG's estimated number of tree species to other tropical countries. To do this, we collected data on the number of tree species of each tropical country from the Global Tree Search Database (GTSD, 2018).[3] The list of tropical countries was based on the International Tropical Timber Organization's (ITTO) statistical database of international tropical forest product producers (ITTO, 2017). The ITTO categorized the tropical countries into three regions; Africa; Asia-Pacific; and Latin America. The average number of tree species per country by region was 1293 for Africa, 3019 for the Asia-Pacific,[4] and 3227 for Latin America. When all tropical countries were compared together, the average number of tree species per country was 2333. By comparison, the estimated number of tree species in PNG was 2843 (GTSD, 2018). When all the tropical countries were assessed for greatest number of tree species biodiversity, PNG ranked number ten. This indicates that the tree species diversity of PNG is similar to many other tropical countries, especially in the Asia-Pacific and Latin American regions. The other primary condition that we found to be vital for achieving financial viability with portable sawmills was the operational capacities of the saw millers. While the average level of completed education is low in PNG, the capability of the people to achieve proficiency in portable saw milling with proper training is no different than any other tropical country. The implication is that our research findings are relevant to other tropical forest locations and should be considered in the design of future CFEs.

5. Conclusion and recommendations

Modelling of NGO-facilitated portable sawmill CFE in PNG revealed that this small-scale sustainable native forest management model has a high probability of failure because operational costs are typically larger than sawn lumber revenues. We determined that achieving financial viability will require the use of professionally trained and experienced sawmill labour, as well as limiting timber harvests to sites with species distributions that have a high commercial value and are located within a reasonable distance to markets. We recommend that future community forestry projects identify opportunities to create value-added products from the rough-sawn lumber to improve the probability of achieving financial viability and reducing the overexploitation of the most valuable commercial species. We also recommended that future organizations which support the commercialization of CBF products conduct a financial/business analysis prior to implementing any activities to conserve resources for financially viable forest management opportunities. We conclude that NGO facilitated portable sawmill and small lumber yard CFEs should not be pursued as a small-scale native forest management model unless adequate human capacities required for commercial activities have been developed and a feasibility assessment indicates a high probability of sustainable profitability.

[3] The Global Tree Search Database did not have any data for Columbia, the Democratic Republic of Congo, and Vietnam.

[4] The island countries of Fiji and Vanuatu were not included in the Asia-Pacific average because the data was dramatically different from the other Asia-Pacific countries, which skewed the average by 20%.

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Declarations of interest

None

Appendix A. Appendix

Table 9
Discount rate sensitivity analysis descriptive statistics for Models 1 and 2 (Thousands 2017 USD).

Model	Mean	Minimum	Maximum	Median	Mode	Standard deviation
Discount rate of 7.35%						
Model 1 (Even distribution harvest)	−737.4	−1427.8	343.9	−787.9	−842.9	254.9
Model 2 (High-grading)	51.02	−657.6	816.3	57.4	−71.2	217.3
Discount rate of 13.65%						
Model 1 (Even distribution harvest)	−668.6	−1199.2	269.1	−712.9	−746.2	218.1
Model 2 (High-grading)	0.6	−603.2	655.9	5.8	−102.9	184.6

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Timber royalty reform to improve the livelihoods of forest resource owners in Papua New Guinea

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ABSTRACT

Inequitable timber resource rents are a problem that has plagued tropical forest management in countries throughout the world, including Papua New Guinea (PNG), which exported 21% of the world's tropical hardwood logs during the last decade. Rural tropical forest resource owners (FROs) often have limited economic resources and resource rents from timber harvests can help them access goods and services that they otherwise cannot afford. This paper uses historical log export data and timber royalty rates to compare the timber resource rents received by FROs in PNG to log export duties and levies collected by the PNG government and the residual cash flows collected by logging companies from log exports. Between 2007 and 2017, PNG's FROs received an annual average of 6.1% of the market value of the logs harvested. By comparison, the PNG government received an annual average of 42.3% from duties and levies and the logging industry received 51.6% for its costs/profits. We also found that the real value of royalties for different timber species has declined by between 32% and 66% since 1991 due to the use of the fixed-rate system. We recommend that future royalty payments in PNG be calculated as a percentage of market value and that there be greater public participation in the determination of the appropriate income split to provide a more equitable distribution of timber harvest revenues between different actors.

1. Introduction

Resource rents from timber harvests are a critical source of revenue for poor forest-dwelling communities in many tropical countries, including Papua New Guinea (PNG). Timber resource rents represent the surplus value of logs after the harvesting costs and normal returns have been accounted for (Repetto, 1990). As the livelihoods of many rural tropical forest resource owners (FROs) are heavily dependent on subsistence agriculture, the rents received from timber harvests provide a significant source of additional income to support their access to economic goods and services. In PNG, approximately 97% of the forests are held under customary land ownership by rural tribal clan groupings (PNGFA, 2009). It is estimated that 42% of the rural population in PNG live below the national poverty line (World Bank, 2009). Gaining access to basic services such as general infrastructure, education and healthcare is a crucial issue for the country's forest-dwelling communities (PNGFA 2009). Due to the limited development and few employment opportunities in rural areas, customary landowners have resorted to selling their forest resources to industrial logging companies to gain access to essential goods and services (Filer and Sekhran, 1998, Bird et al., 2007, PNGFA 2009).

Approximately 90% of the logs harvested by logging companies in PNG are exported (PNGFA, 2009). In 2001, approximately 1.6 million cubic metres (m^3) of non-coniferous topical logs were exported from PNG (PNGFIA, 2010), and by 2017 this volume had nearly doubled to just over 3.1 million m^3 (SGS, 2018). PNG's log exports represented 21% of the total non-coniferous log exports from all tropical countries during the years 2001 to 2016 (ITTO, 2017). It has been estimated that there are roughly 25 foreign logging companies operating in PNG, with most being from Malaysia (PNGFA, 2009). Most of these companies are subsidiaries of one large Malaysian conglomerate, which controls approximately 45% of the logging and log exports in PNG. This conglomerate and four other companies control about 80% of the PNG log export market. All logs exported from PNG are subject to export duties. The duties for log exports are calculated with a progressive tariff rate based on the Free on Board (FOB) market value[1] of the log exports (PNGC, 2012). In addition to the log export duties, the PNG Forestry Act (1991), under Section 120, describes conditions for levy payments

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[1] FOB market value is the monetary value of the log delivered to a mill or port of export. In this paper, the term 'market value' is a reference to the FOB market value of the timber.

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to the PNG government and timber royalty payments to the FROs to be made by all entities conducting timber harvests. The current timber royalty rate system uses a minimum fixed-rate per m^3 of timber harvested. This minimum fixed-rate per m^3 varies between species. The timber royalties are collected by the PNG government from the logging companies and then redistributed to the FROs.

The timber resource rents received by FROs in many tropical countries are considered inequitable (Ascher, 1998; Dauvergne, 1999; Thanakvaro, 2002; Amacher et al., 2007; Sinclair, 2008). Being denied fair resource rents from industrial timber harvests can be an impediment to the economic development of FROs because few other small-scale forest management opportunities are available to them (Scudder et al., 2018). No published information exists on how the total annual timber royalty payments revenue received by PNG's FROs compares to log duties and levies received by the PNG government and the net returns to the logging industry. Without this information, it is not possible to determine if the current royalty rates represent an equitable resource rent for the timber harvested. In this study, we estimate the royalty payments made to FROs and compare these to the export duties and levies received by the PNG government and the estimated net returns to logging companies. The three research objectives were to; 1) estimate previous timber harvest cash flow distributions in PNG; 2) evaluate the inflation-induced erosion of the real values of the fixed-rate royalties per species; and 3) determine how the livelihoods of PNG's FROs could be improved if royalty payments were calculated as a percentage of market value.

In the next section of the paper, we discuss the methods used to address our research objectives. We then present our results of estimated timber harvest cash flow distributions, the erosion of the real value of timber royalties, and how cash flow distributions would change if royalties were calculated as a percentage of market value. Finally, we present our key findings and provide recommendations to improve the existing timber royalty payment system in PNG.

2. Methods

2.1. Data collection

We collected log export reports produced by Sociele Generale de Surveillance (SGS), (SGS, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018). SGS is an independent log export auditor that works on behalf of the PNGFA. The information extracted from the log export reports was the log export volumes by species, the FOB value of logs exported, and the duty and levy payments paid to the PNG government by the logging companies. We collected additional data on the levy payment requirements from the PNGFA (2018). The levy payment requirements for log exports total 35.5 (PGK) per m^3. The PNG government uses these levies to fund a variety of activities; provincial and local-level government (LLG) infrastructure and business development (45%); reforestation and monitoring (17%); administrative expenses (16%); education (11%); home construction (6%); and spiritual activities (6%) (PNGFA, 2018). The fixed-rate royalty payment rates by species were extracted from a PNG National Forest Service (PNGNFS) document titled ‘Form 221’ (NFS, 2008). Data on consumer price indices and foreign exchange rates was retrieved from the Bank of Papua New Guinea (BPNG) website (BPNG, 2018).

2.2. Data analysis

For this analysis, we completed a log export revenue cash flow distribution for the years 2007–2017. We calculated the erosion of the real value of royalty payments for the years 1991–2017. We calculated the royalty rates as a percentage of market value for the years 2007–2017. We addressed the three research objectives through an analysis conducted using Microsoft Excel software.

For the log export revenue cash flow distribution analysis, log volumes and FOB export values were only collected from the SGS report sections labelled ‘Saw/Veneer logs’ and ‘Low-grade logs’, which represent the native forest log exports. The SGS report sections labelled ‘Plantation logs’ are not subject to duties, levies and royalties, and therefore were not included in this study. Royalty payments were calculated using the SGS log export volumes by species and the minimum-required fixed-rate royalty payments by species, which was extracted from the PNGNFS's ‘Form 221’ (NFS, 2008) (Table 1). These timber species in PNG are categorized into four groups, with Group 1 representing the most sought-after export species. The fixed-rate royalties have been in effect since 1 March 2008. Before this date, the minimum fixed-rate was 10 Kina (PGK) per m^3 for all species, which was set by the PNG Forestry Act (1991). The effect of inflation is such that the real value of fixed-rate royalties become eroded over time.

Table 1
PNG timber royalty rates per m^3 (2017 PGK and USD).

Group/Species	PGK	USD
Group 1		
Intsia bijuga	35.00	\$11.22
Palaquium spp.	20.00	\$6.41
Dracontomelon dao	20.00	\$6.41
Remaining Group 1 species	15.00	\$4.81
Groups 2, 3 and 4 species	10.00	\$3.20

We calculated the erosion of the royalty payment real values by using inflation rates collected from BPNG (2018) and the royalty rate amounts extracted from NFS (2008). For each year before 2017, the royalty payment real values were increased in proportion with the accumulated inflation. We also developed a projection of potential royalty payments that could have been received by FROs by using market value percentages between 8% and 20%, with 2%-unit increments. These market value percentages were chosen to demonstrate what FROs could have received if royalties had been larger than the current rate. With this projection, we assumed that all harvest volumes remained the same. Estimates were generated for the total additional royalty revenues that would have been received, additional royalties per m^3, and the additional royalties received by each province in PNG. All the revenue, duty, levy and royalty values were converted to 2017 USD using consumer price indices and foreign exchange rates retrieved from BPNG (2018).

3. Results

3.1. Timber harvest cash flow distributions

We found that the total timber royalty payments that PNG's FROs received during the years 2007-2017 was \$196.6 million (real 2017 USD). Proportionally, this amounted to an average of 6.1% of the total annual log export revenues. By comparison, the PNG government received \$913 million (real 2017 USD) from log export duties. This represents an average annual proportion of 27.8% of the log export revenues. Levy payments to the PNG government were \$479 million (real 2017 USD), which amounted to an average of 14.6%. The annual average proportion remaining for logging company costs/profits was 51.6%. The average value that FROs received in royalty payments was \$6.03 per m^3 in real 2017 USD. By comparison, an average of \$41.78 per m^3 went to the PNG government in the form of duty and levy payments. The average remaining portion retained by the logging industry for costs and profits was \$50.44 per m^3. Tables 2 and 3 provide details of the total distribution of cash flows and distributions by m^3 for the years 2007-2017.

3.2. Erosion in real value of royalty payments

We found that the erosion in real value of the royalty payments was

Table 2
Total cash flow distributions for PNG log exports during the years 2007–2017 (millions of real 2017 USD and % of total revenue).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Log export cash distribution (millions of 2017 USD)											
Total log export revenues (FOB)[a]	295.1	225.8	202.3	311.5	312.7	245.0	287.1	361.5	375.2	367.4	306.1
Forest resource owner royalty payments	14.1	16.3	14.6	19.7	21.8	19.0	19.6	20.8	19.7	18.1	15.4
PNG government											
Duties	80.4	61.4	55.2	85.6	86.3	66.4	78.2	98.9	101.8	99.3	99.4
Levies	49.9	41.1	32.5	45.2	51.2	43.3	43.8	48.7	46.8	41.0	35.5
Logging industry residual return for cost/profit	150.7	107.0	100.0	160.9	153.4	116.3	145.4	193.2	206.9	209.1	155.7
Log export cash flow distribution (%)											
Total log export revenues	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Forest resource owner royalty payments	4.8	7.2	7.2	6.3	7.0	7.7	6.8	5.8	5.3	4.9	5.0
PNG government											
Duties	27.3	27.2	27.3	27.5	27.6	27.1	27.2	27.3	27.1	27.0	32.5
Levies	16.9	18.2	16.1	14.5	16.4	17.7	15.3	13.5	12.5	11.2	11.6
Logging industry residual return for cost/profit	51.1	47.4	49.4	51.7	49.1	47.5	50.7	53.4	55.1	56.9	50.9

[a] FOB (Free on Board) refers to the value of the logs at the port of loading.

different for all timber species groups. PNG has experienced an average annual inflation rate of 7.4% between the years 1991 and 2017 (BPNG, 2017). In 1991, the real value of royalties for all species groups was \$9.42 per m^3 (2017 USD). By the end of 2007, the real value for all species groups had declined to \$5.18 per m^3 (2017 USD). In early 2008, the royalty rates for Group 1 species were re-set by the PNG Forest Minister. Under the new rates, the real value in 2017 USD in 2008 was \$16.93 per m^3 for *Intsia bijuga*, \$9.67 per m^3 for *Dracontomelon dao* and *Palaquium* spp., and \$6.92 per m^3 for all remaining Group 1 species. The royalty rates for Groups 2, 3 and 4 species were not changed and further declined to \$4.84 per m^3. By 2017, the real value of royalty rates for all species groups had declined by 34% of their 2008 values (Fig. 1).

3.3. Royalty payments as a percentage of market value

We found that calculating royalty payments as a percentage of market value at ranges of between 8% and 20% for the years 2007-2017 would have resulted in PNG's FROs receiving additional revenues of between \$267.0 and \$667.7 million (real 2017 USD). As the FROs had received only a relatively small portion of the harvested timber values, the 2% incremental increases in the royalty rates would equate to substantial growth in revenues received (Fig. 2). For example, the royalty revenues received by the FROs for the years 2007-2017 in real 2017 USD would increase by 32% (8% royalty rate), 65% (10% royalty rate), 98% (12% royalty rate), 131% (14% royalty rate), 164% (16% royalty rate), 197% (18% royalty rate) and 230% (20% royalty rate). Furthermore, the total additional revenues would have remained in the provinces where the timber was harvested (Fig. 3).

4. Discussion and recommendations

Our analysis indicates that PNG's FROs have received little compensation for timber harvested on their lands. Despite owning the timber resources, the FROs have only received an average of 6% of the market value of the timber harvested from their lands. Almost all (94% on average) of the value of the logs has been captured by the PNG government and the logging industry. As the log export duties flow to the PNG central government, a substantial portion of the cash flows generated by timber harvests are not staying within the control of PNG's rural communities. The PNG government designates a majority portion of the levies collected to projects designed to benefit FROs at the provincial and LLG areas. However, the FROs usually do not have control over how these monies are spent. The levy payments designated for local development are typically received by provincial and LLG governments, LLG committees, and Landowner companies. Politicians in PNG are often accused of rewarding a very small portion of their constituents to ensure their political survival (Filer and Sekhran, 1998). The landowner companies have been found to be deficient in their financial representation of FROs (Filer and Sekhran, 1998; Bird et al., 2007). Even when levy payments are used to fund prudent development projects, it does not aid FROs in accessing crucial needs, such as healthcare, school fees, and store-bought goods. The existing arrangement appears to be skewed in favour of the government and the logging companies, rather than the FROs.

There has been a substantial erosion in the real value of the royalty payments to PNG's FROs between 1991 and 2017. This is a direct result of the fixed-rate royalty system. The real value of royalties for over 90% of the timber volume harvested during the last decade has been eroded by 32–66% of the real values in 1991. By comparison, log export duties collected by the PNG government are calculated with a progressive tariff rate based on the FOB value of the log exports, which protects the tariff rate from the erosion of real values caused by inflation.

An unintended consequence of the low royalties paid to communities and/or poor enforcement capacity has been the creation of an informal sector of illegal small-scale timber harvesting in the country's native forests. Little is known about the harvest volumes associated with this informal sector or the destinations of the timber, as the PNG government does not have the resources to track or regulate this sector. Anecdotal evidence suggests that the illegally harvested timber is milled with portable sawmills by individuals lacking the financial means to obtain a harvest permit, but wanting a better return for their timber than that can be received from royalty payments. Potential

Table 3
Average revenues received per m^3 during the years 2007–2017 (real 2017 USD).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Log export revenues (FOB)[a]	\$108.52	\$94.25	\$101.84	\$107.96	\$92.66	\$82.87	\$92.15	\$100.13	\$102.60	\$107.88	\$89.86
Royalties	\$5.17	\$6.82	\$7.35	\$6.84	\$6.46	\$6.42	\$6.31	\$5.76	\$5.39	\$5.31	\$4.53
Log export duty	\$29.58	\$25.61	\$27.81	\$29.69	\$25.57	\$22.47	\$25.09	\$27.39	\$27.84	\$29.15	\$29.18
Log harvest levy	\$18.36	\$17.13	\$16.35	\$15.67	\$15.17	\$14.64	\$14.07	\$13.48	\$12.80	\$12.04	\$10.43
Logging industry residual	\$55.41	\$44.68	\$50.33	\$55.77	\$45.46	\$39.34	\$46.68	\$53.50	\$56.57	\$61.39	\$45.72

[a] FOB (Free on Board) refers to the value of the logs at the port of loading.

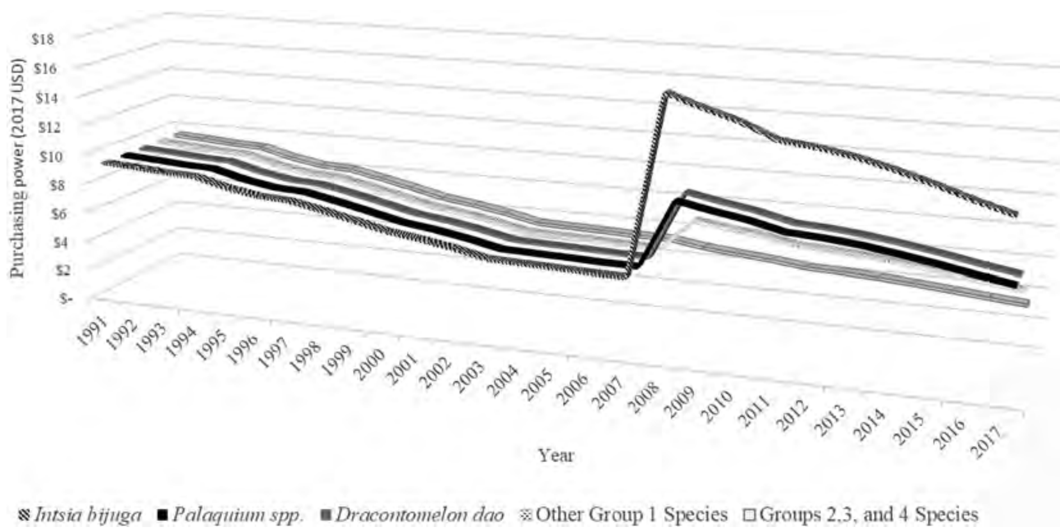

Fig. 1. Erosion of the real value of royalty payments by species for the years 1991–2017 (2017 USD).

negative externalities of the informal sector are forest degradation from poor logging practices, timber theft and over-harvest of species with high economic values.

Royalty payments based on a percentage of FOB market value (like the current system of log export duty calculations in PNG) can help address the inequity that has arisen through PNG's current system of a fixed-rate for royalties. Our analysis found that if royalties were calculated at rates of between 8% to 20% of market value, the additional cash flows received by PNG's FROs during the years 2007–2017 would have increased by between approximately 32% and 230%. Increasing royalty payments to communities would also mean that a higher proportion of the resources rents would be retained within local communities, thus giving FROs greater capacity for self-funded economic development. Furthermore, if the percentage of the market value selected for the royalties was greater than timber prices offered in the informal market, the scale of the smallholder illegal logging and the associated negative externalities could be reduced. Under the current system in PNG, the administrative costs for estimating royalties owed are shared by SGS (Independent log export auditor) and the PNG government. SGS estimates the log volume exports by species. The PNG government uses this data and their own internal data to calculate and collect royalties owed from the logging companies, and then re-distributes the royalties to the landowners. We believe that increasing the royalty amounts should not result in additional costs to SGS or the PNG government, since these activities are already being performed.

An increase in royalty paid to communities in PNG would need to be funded by either: (1) a reduction in duty/levy payments retained by the PNG government and reallocation of this to communities, either through a direct payment to communities or indirectly through increased royalty rates on a stumpage basis, and/or (2) a reduction in the residual cash flows to the logging industry and a redistribution of this money to communities through increased royalty payments. In terms of

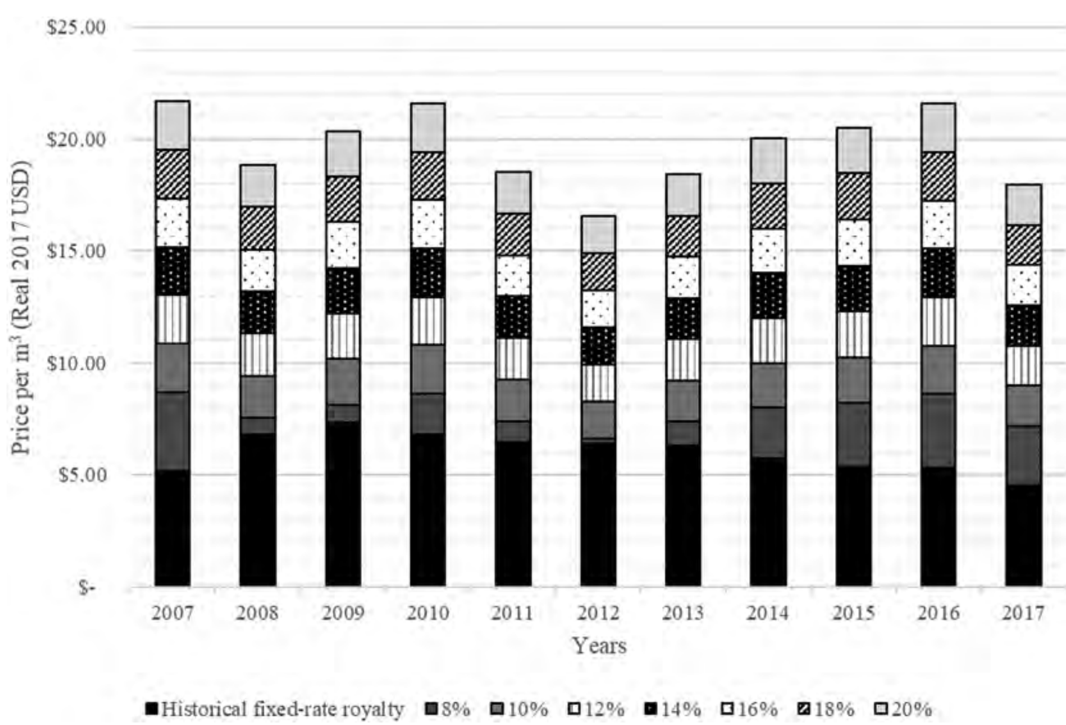

Fig. 2. Additional revenues that would have been received with the incremental increases in royalties as a percentage of market value.

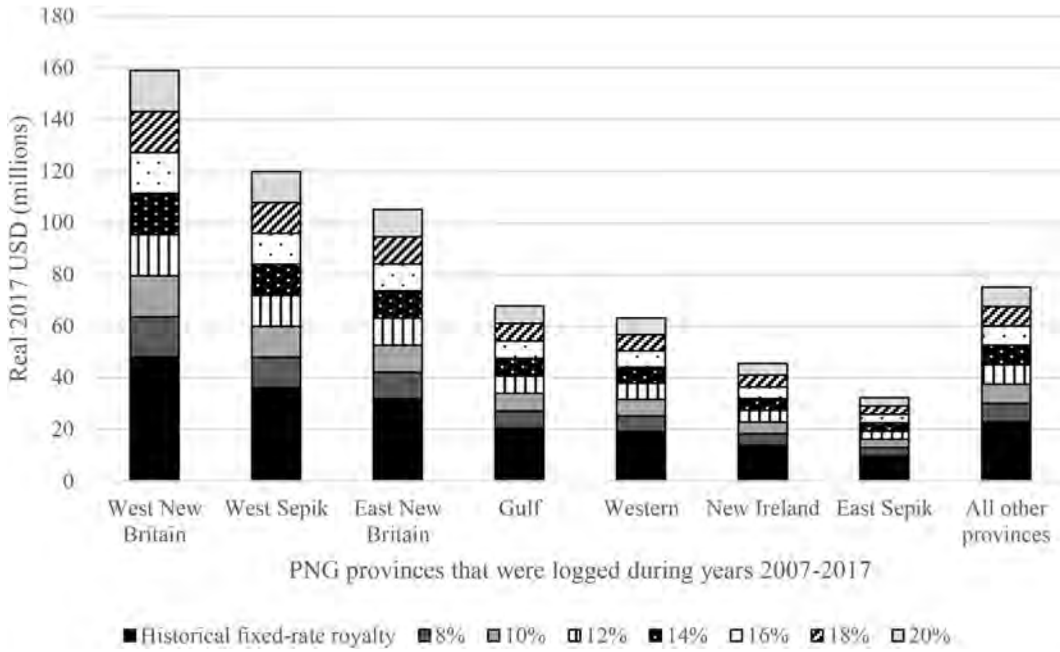

Fig. 3. Additional revenues that would have been received by province with the incremental increases in royalties as a percentage of market value.

the first option, the PNG government has collected an average of 42% of the export FOB log values during the last decade, which could effectively meet the percentage of market value royalties modelled in this study (8–20%). For instance, a 13% decrease in duties would be required to fund a 13% increase in royalties, resulting in both duties and royalties being approximately 18% of the export FOB log values.

Determining whether logging companies could pay higher royalties to communities and remain profitable is difficult. There is little publicly available data on the operational costs of companies, and there are also issues with transfer pricing, and whether log export prices accurately reflect revenues and profits of the logging industry. In the most recent logging cost study in PNG, it was estimated that the average total logging cost (not including royalties, duties and levies) was $160.83 per m^3 (expressed in real 2017 USD) (FORTECH, 1998). Our analysis found that the average residual return for logging companies after paying royalties, duties and levies was $50.44 per m^3 (expressed in real 2017 USD). This suggests that either the logging industry has been operating at a loss for many years or that the reported logging costs have been inflated and/or revenues deflated. In a 2006 report prepared for the PNG Forest Industries Association, PricewaterhouseCoopers (PwC), stated that ‘Logging companies themselves appear to be in a contradictory position. While current official log prices indicate that the industry has been unprofitable for a number of years, logging continues and companies still seek access to new forest areas, and make significant investments in other areas of the economy’ (PwC, 2006, p.9). Furthermore, an investigative report by Mousseau and Lau (2016) found that logging companies in PNG declare little to no profits by artificially inflating logging costs and under-pricing their logs relative to log exports in other tropical countries.

The practice of under-pricing logs is a form of ‘transfer pricing,’ which is often done to reduce the amount of taxes paid. The practice of transfer pricing in PNG has also been reported by Grynberg et al. (1988), Marshall (1990), and Hunt (2002). During the years 2012–2016, PNG's non-coniferous log export price was 30% to 76% less than the average price of other Asia-Pacific island nation log exporters (Fiji, Indonesia, Malaysia, Philippines and Vanuatu) (ITTO, 2017). One possible further cause for the low log prices relative to other Asia-Pacific island nations is higher export shipping prices in PNG. However, the shipping pricing system in PNG is so opaque that it is not possible to discern if this is the reason for the low log export prices. While these reports indicate that un-reported income is being accrued, they do not show if total profits represent a fair financial return typical of tropical forest logging companies. In the absence of accurate logging cost and pricing data, it is not possible to determine if logging industry profits are excessive and whether some of these profits could be applied to increase royalty payments to communities.

We also analysed the changes in price elasticities for each of the log species/groups for years 2007–2017, to see how increases in royalty rates would affect log demand for logging companies. We found that an increase or decrease in price did not result in a discernible pattern of corresponding increases or decreases in harvest volumes. The average elasticity across all species over ten years was -0.14, indicating timber harvests in PNG are inelastic. We believe that the reason log demand appears to be inelastic in PNG is the high level of species diversity in PNG's forests. Logging companies are harvesting all the trees within their timber concessions that have a diameter greater than 50 cm DBH, regardless of species. A change in the per unit market price of an individual species is not altering the harvesting practices of the logging companies. It is likely that fluctuations in harvest volumes by species is due to the random species distributions within the timber concessions. In the absence of accurate logging cost and pricing data, it is not possible to determine if increased royalties would reduce the logging industries demand for logs.

Other Melanesian countries (i.e. Fiji, the Solomon Islands and Vanuatu) have acted to correct similar inequities in payments made to communities associated with sales of their timber resources. The Solomon Islands Forests Bill (SIFB) requires that timber royalties shall, at a minimum, be the greater of either 10% of the determined timber value or the amount fixed by the Forest Commissioner (SIFB, 2004). Furthermore, the SIFB states that the determined timber value estimates will be based on world prices and not the actual sale price of the timber to avoid a reduction in royalty payments caused by transfer pricing (SIFB, 2004). In Fiji, the Forestry Bill requires that the timber royalty rates be reviewed every five years with new rate decisions based on consultation with all stakeholders (FFB, 2016). In Vanuatu, the most recent revision of the National Forest Policy was completed with public participation from landowners, private businesses, NGOs, provincial governments, and national government agencies (VFP, 2011). The objective of the broad public participation was to develop a new forest policy that represented a negotiated agreement amongst all stakeholders (VFP, 2011).

It should be noted that increasing the timber royalties paid to FROs will not necessary result in them attaining improved long-term livelihoods. One potential challenge to the economic development of FROs is their capacity to manage personal finances. Only 15% of the population in PNG has a bank account (Bakani, 2018). In the absence of a bank account, the majority of FROs do not have a safe place to store their money. Furthermore, in the rural areas of PNG, the levels of attained education are low relative to the rest of the country. The highest level of education attained by approximately 49.3% of rural people is elementary (Ages 6–8 years) (NSO 2011). Approximately 33% have completed primary education (Ages 9–14 years), and just 13% go on to complete secondary education (Ages 15–18 years) (NSO 2011). Less than 5% of the rural population goes on to achieve additional tertiary education (NSO 2011). This indicates that the capacity for managing personal finances may need to be improved. Increasing royalties for FROs without addressing personal finance education would likely result in little change towards improving FRO livelihoods over the long-term.

Our findings indicate that the existing royalty rate system in PNG has resulted in the country's FROs receiving an inequitable share of forest resource rents. Based on our findings and the reforms of other Melanesian countries, we make the following three recommendations for a fairer distribution of timber harvest revenues and improvements in the future management of PNG's forest resources.

1) Existing forest policy be reformed to require timber royalty payments be changed to the greater of either the minimum fixed-rate as set by the Forest Minister, or to a percentage of FOB market value, as reported by Sociele Generale de Surveillance. This change to royalty payment policy would protect PNG's FROs from the real value of future royalties being eroded by inflation.

2) The minimum percentage of market value selected for the royalty-rates should represent an equitable distribution of log export revenues. In 2017, PNG's FROs received royalties that averaged 5% of the value of the country's export log market. Between 2007 and 2017, the percentage of market value that FROs received varied by species and ranged between 2.7% and 13.1%. It is recommended that a percentage of market value be selected that, at a minimum, is equivalent to historical market distributions and equates to a value per m^3 that is greater than those being received by participants in the informal sector. Further research will need to be conducted to identify variations of informal sector prices throughout PNG.

3) Increased public awareness of existing forest rent distribution and increased public involvement for determining the percentage of the market value for timber royalties. It is important that all stakeholders are fully informed on the existing forest rent distributions, so that an informed dialogue can take place. Increased participation by all stakeholders is an approach that focuses on reaching a negotiated agreement that best meets the interests of all parties. Participation could take a variety of forms, including landowner consultations, local and national discussion forums, and public review of government decisions. One initiative that is positioned to aid in facilitating increased public participation on royalty reform is the Papua New Guinea Governance Facility (PGF). This initiative is being spearheaded by the PNG and Australian governments and it is dedicated to improving governance in PNG, including increased citizen participation (DFAT, 2015).

5. Conclusion

This study found that the fixed-rate royalty payments received by FROs in PNG are small when compared to the duties and levies collected by the PNG government and the residual returns of the logging industry. Furthermore, the real value of these royalties has been eroded. Forest policies in other Melanesian countries present options for policy reform that could be applied in PNG. Reforming the existing royalty payment policies to reflect a fairer percentage of market value will improve the livelihoods of PNG's FROs, and protect future royalty payments from further real value erosion. Incorporating public participation into the timber royalty decision-making process in PNG will allow for the identification of fairer timber royalty payments that are balanced between the needs of the country's FROs, the national government and the logging industry.

Declarations of interest

None.

Acknowledgements

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Introduction to Forest Finance – Online Workshop Report

Report prepared for activity 3.6 of the ACIAR Project
FST/2016/153 'Enabling Community Forestry in PNG'

By Micah Scudder
April 2022

1 Introduction:

During the project mid-term review, one of the reviewers suggested that a forest finance workshop be implemented to introduce the PNG project partners to some of the financial analysis methods conducted in activity 3.6. This financial analysis utilized discounted cash flow DCF modelling. The workshop was presented over three days via zoom. The workshop activities included Microsoft PowerPoint lectures, video tutorials, workbook practice problems, and financial analysis exercises utilizing Microsoft Excel spreadsheets. The workshop was attended by TFTC staff, PNGFA staff, PNG FRI staff, and RAIL staff.

2 Workshop dates and subjects:

Tuesday 5th April (10:00 AM - 12:00 PM):

- Introduction to forest-based finance
- Financial mathematics
- Compounding, discounting, interest rates & time periods

Wednesday 6th April (10:00 AM - 12:00 PM):

- Net present value & capital budgeting
- Financial analysis of a teak plantation in spreadsheet software
- Optimal forest rotation age

Thursday 7th April (10:00 AM - 12:00 PM):

- Introduction to variable costs, fixed costs, & cost-volume-profit analysis
- Portable sawmill & value-add processing break-even analysis in spreadsheet software

3 Workshop materials:

The materials produced for the workshop include a 'Forest-based Finance Workbook' (Appendix 48), a Microsoft Excel Teak Plantation Financial DCF model template, a Microsoft Excel Cost-Volume-Profit Model template for portable sawmilling and value-add manufacturing, and six video tutorials. Website links to the Microscoft Excel templates and video tutorials are provided below.

3.1 Microsoft Excel Template links:

Link to Spreadsheet Financial Analysis Template – Teak Plantation:
https://docs.google.com/spreadsheets/d/1OA4acGwUjDIxX_9_iUiq-EzAMSg9cXR9/copy

Link to Spreadsheet Financial Analysis (Completed Answers) – Teak Plantation:
https://docs.google.com/spreadsheets/d/1-CaMN3ayXsmSocWlKW5nTWiJLCZyTFwj/copy

Link to Spreadsheet Cost-Volume-Profit Analysis:

https://docs.google.com/spreadsheets/d/1DPkVmPAc5NdZnycqJ6ZmQFjHmIXikwXjtJXUbAk4I0c/copy?usp=sharing

3.2 Video tutorial links:

Video – Introduction to Forest Finance:
https://vimeo.com/574289713

Video – Time Value of Money:
https://vimeo.com/574276245

Video – Compounding and Discounting:
https://vimeo.com/574278282

Video – Interests Rates and Time Periods:
https://vimeo.com/574747749

Video – Net Present Value & Capital Budgeting:
https://vimeo.com/574748284

Video – Optimal Forest Rotation:
https://vimeo.com/577820457

Introduction to Forest-based Finance

Training Workbook

Prepared by,
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January 2022

Table of Contents

Preface

This workbook has been prepared to supplement presentations for the 'Introduction to Forest-based Finance Training Workshop,' and to serve as a reference to workshop participants. This workshop was put on for ACIAR Project FST/2016/153.

The objectives of this workshop are to:

- Introduce the subject of finance and relate it to forest management.
- Provide foundational training in financial mathematics.
- Present the capital budgeting process and its application in forest management.
- Familiarize workshop participants with conducing forest-based financial analysis with spreadsheet software.

The tools needed for this workshop are:

1. Pen or pencil.
2. Scratch paper for completing exercise problems.
3. Calculator – Ensure that your calculator has an y^x key (exponent), and an ln key (natural logarithm). These keys will be needed to complete the exercise problems. Most smart phones are equipped with a digital calculator that has these keys. A financial calculator can also be used, if preferred.
4. Spreadsheet software – Microsoft excel, Apple spreadsheets, and Google Sheets are all acceptable options.

Throughout this workbook, there are several QR code boxes and website links that will take you to educational videos. These videos are a training tool to supplement the lessons in this workshop. Project participants can view these videos as often as they want, at any time during or after the workshop. The QR codes can be scanned with a smart phone or tablet camera to access the videos. If the participants are viewing this workbook on a desktop or tablet, they can press the control key on their keyboard and click the web address link or copy and paste the web address into their web browser.

Prework for Workshop

There are two prework items for this workshop. This first item is the completion of a short 5-question survey. The purpose of this survey is to give the workshop facilitators an approximation of the current financial knowledge of workshop participants, and for the participants to share any learning objectives they would like to have included in the workshop.

Link to Prework Survey
https://forms.office.com/r/eMf0eWUqnL

The second item of the prework is brief review of the order of mathematical operations. This prework item is optional and has been included to assist workshop participants in competing the financial mathematical exercises. Understanding the correct order of operations is necessary deriving the correct answers to exercise problems. When completing the mathematical problems, follow the PEMDAS order of operations (see below).

Table 1: Order of operations for mathematical problems

P	**E**	**M**	**D**	**A**	**S**
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Parentheses	Exponents	Multiplication	Division	Addition	Subtraction
( )	a^2	X	÷	+	-

1 Introduction

Finance is often one of the least taught subjects in forestry education. This may be because it is too divergent from traditional forestry subjects, such as ecology and silviculture. Another possibility is that financial mathematics may appear to be too difficult, with abstract and confusing formulas. The problem this creates is that in forest management money plays a large role in the decision-making process. Management decisions can be broken down into a series of activities that will take place. Activities cause costs to occur, and costs must be paid for with money. There is never enough money to implement every desired management activity. Consequently, there is a need for foresters to understand financial management to aid them when making forest management decisions.

2 What is Finance?

Finance is about the management of money. The role of finance is to make sure that there is enough money to pay for the expected expenditures and to make sure that money is spent and invested wisely. It includes a wide variety of subjects, some of which are investing, lending, saving, and budgeting. Finance is typically split into three categories: personal finance, corporate finance, and public finance.

Personal finance is specific to an individual's existing financial position, which is based on a person's earnings, living expenses, and future goals. Personal finance focuses on developing strategies to meet a person's future needs such as retirement, subject to their daily living expenses/constraints.

Business finance refers to the financial activities for running a business. These activities including raising money for the business and which activities they should spend their money on. When a business needs to raise money it typically does this by issuing bonds or offering stock. Bonds are a unit of debt that pay a fixed interest rate to the bond holders. Stocks are a type of security that give the owners a proportionate ownership in the business. When a business makes decisions about which activities to pursue, they are undertaking capital budgeting, which is a method for evaluating potential projects or investments.

Public finance refers to how a government pays for the services that it provides to the public. Governments primarily raise money through various types of taxes and issuing bonds. The money that governments raise is supposed to then be budgeted and spent to maintain a stable economy and provide adequate social programs to taxpayers.

Video – Introduction to Forest Finance
https://vimeo.com/574289713

3 Financial Mathematics

A financial asset is a resource that is owned by a person or organization that is regarded as having value that can be used to generate future benefits that can be converted to money. The aim of financial mathematics is to identify the value of assets.

3.1 Time value of money

Would you rather have an asset that promises to pay you $100 in three years' time or an asset that promises to pay you $100 today? Most of us will always choose to have the $100 today. If we received that $100 today, we could spend it, or invest it in a savings account that pays us interest. Over that three years of time our money will have grown is size. If we had chosen to get the $100 in three years, we never would have had the opportunity to enjoy it by making purchases, or to invest it to grow to larger value. The idea that $1 today is worth more than $1 dollar at some point in the future is referred to as the time-value of money.

Video – Time Value of Money
https://vimeo.com/574276245

3.2 Interest

Interest is the charge for borrowing money, which is typically expressed as a percentage rate. When you invest money into a savings account, the bank is borrowing your money and will pay you a percentage rate to do so. When you borrow money from a bank or another person, you pay the interest to them.

3.2.1 Simple interest

With simple interest, the interest earned or paid is based on the initial amount of money invested or borrowed, called the principle. If you had a principle of $100 and invested it in a savings account that paid an annual interest rate of 5%, how much money would you have in three years? To solve this problem, we use the 'Future Value' formula.

Future Value formula with Simple Interest

$$FV = PV(1 + i)$$

Where:
$FV = the\ accumulated\ future\ value\ of\ the\ money$
$PV = the\ principle\ or\ what\ the\ money\ is\ worth\ today$
$i = the\ interest\ rate$

Example Exercise A

In this example, the interest rate is 5% per year, and the investment time period is three years. Before we can solve the formula, we must convert the interest rate to one that is for the entire three years.

Step 1: $i = 0.05 * 3$

$i = 0.15 \; or \; 15\%$

Now we can complete our original formula.

Step 2: $FV = 100(1 + 0.15)$

Step 3: $FV = 100(1.15)$

Answer: $FV = 115$

In three years, our investment of $100 will have grown to $115 with a simple annual interest rate of 5%. The bank will have paid us an interest of $15 for the privilege of borrowing our $100 principle for three years.

3.2.2 Compound interest

With simple interest, the interest is earned or paid at the end of the agreed upon time period. In the example above, that time period was three years. With compounding interest, the interest is earned or paid at each compounding period.

Example Exercise B

To illustrate compound interest, lets modify our original example to interest that compounds every year for three years.

Year 1

Step 1: $FV = 100(1 + 0.05)$

Step:2 $FV = 100(1.05)$

$FV = 105$

Year 2

Step 3: $FV = 105(1 + 0.05)$

Step 4: $FV = 105(1.05)$

$FV = 110.25$

Year 3

Step 5: $FV = 110.25(1 + 0.05)$

Step 6: $FV = 110.25(1.05)$

Answer: $FV = 115.76$

In three years, our investment of $100 will have grown to $115.76 with a compounding annual interest rate of 5%. The bank will have paid us an interest of $15.76 for the privilege of borrowing our $100 principle for three years.

In Example Exercise B, our money increased by $0.76. This may not seem like much of a change, but what if we left it in the savings account for 50 years? How much different would the total be between simple interest and compound interest? Using the same formulas, in 50 years we would have these two totals.

***Simple interest*:** **$350**
***Compound interest*:** **$1,147**

Which amount would you rather have? In this example, the compound interest method gives us more than three times the amount of money when compared to the simple interest method. In this example, the bank would have paid us $1,046.74 in interest for the privilege of borrowing our principle of $100 for 50 years. That interest payment is the time-value of our original $100.

3.3 Compounding and discounting

3.3.1 Future value formula

You may have noticed that in the above example we had to complete six steps to solve the three mathematical equations, since the problem had a three-year timeline. Using this approach, it would take a lot of work to calculate problems with long time horizons like 50 years. The good news is that there is a shorter way presented in the formula below. Compound interest is a mathematical process that allows us to compare different dollar amounts in time that have the same value given a specific interest rate.

Future Value formula with Compound Interest

$$V_0 = V_n(1+i)^n$$

$V_0 = Future\ value$
$V_n = Present\ value$
$i = Interest\ rate$
$n = Number\ of\ time\ periods$

Note: You may notice that some of the symbols have changed in the future value formula. Previously, future value was symbolized by FV, and present value was symbolized by PV. In the remaining formulas in this workbook, future value is symbolized by V_n and present value is symbolized by V_0. For future value, the V stands for value and the subscript n stands for the number of time periods in the future. For present value, subscript 0 stands for year zero, the value right now in the present.

Example Exercise C

Let's revisit our problem from above. If we were going to invest $100 at 5% interest for 50 years, how would we solve for the future value. To solve this problem, we would use the following equation:

Step 1: $V_n = 100(1+0.05)^{50}$

Step 2: $V_n = 100(1.05)^{50}$

Step 3: $V_n = 100(11.467)$

Answer: $V_0 = 1{,}146.74$

In this example exercise, we were able to solve the problem in three steps using the future value formula with compound interest. It would have taken us 100 steps to get the same answer if we used the approach in Example Exercise B.

3.3.2 Present value formula

The present value formula is derived from the future value formula, presented above. What if we knew that at a certain point in the future, we were going to receive a sum of money and we want to know what it is worth today (present value). If we rearrange the future value formula, we can derive the present value of a future sum. With the present value formula, the interest rate is referred to as the discount rate because it discounts the values that will be received in the future to their value in the present.

Present Value formula

$$V_0 = \frac{V_n}{(1+i)^n}$$

$V_n = Future\ value$
$V_0 = Present\ value$
$i = Interest\ rate$ (also refereed to as the *discount rate*)
$n = Number\ of\ time\ periods$

Example Exercise D

Let's say that we expect to be receiving \$27,000 in five years. If we use a discount rate of 5%, what is this worth today? To solve this problem, we would use the following equation:

Step 1: $V_0 = \frac{27{,}000}{(1+0.05)^5}$

Step 2: $V_0 = \frac{27{,}000}{(1.05)^5}$

Step 3: $V_0 = \frac{27{,}000}{1.276}$

Answer: $V_0 = 21{,}159.87$

The \$27,000 that we will be receiving in 5 years is worth about \$21,160 today if we use a discount rate of 5%.

Video – Compounding and Discounting
https://vimeo.com/574278282

3.3.3 Interest rate formula

The interest rate formula is used to calculate the interest earned if you already know the present value, future value, and the number of time periods that will occur. The interest rate formula is sometimes referred to as the internal rate of return (IRR).

Interest rate formula

$$i = \left(\frac{V_n}{V_0}\right)^{\frac{1}{n}} - 1$$

$V_n = Future\ value$
$V_0 = Present\ value$
$i = Interest\ rate$
$n = Number\ of\ time\ periods$

Example Exercise E

Let's say that we invested $1,000 that grew to $5,000 in seven years. To figure out what our annual interest earned, or what the IRR was, we would use the following equation:

Step 1: $i = \left(\frac{5{,}000}{1{,}000}\right)^{\frac{1}{7}} - 1$

Step 2: $i = (5)^{\frac{1}{7}} - 1$

Step 3: $i = (5)^{0.143} - 1$

Step 4: $i = 1.258 - 1$

Answer: 0.258 or 25.8%

If our invest grew from $1,000 to $5,000 in seven years, we would have earned an annual interest of 25.8% on our initial investment.

3.3.4 Time period formula

The final variation we can make from our original Future Value formula is to rearrange it to solve for the number of time periods.

Time period formula

$$n = \frac{ln\left(\frac{V_n}{V_0}\right)}{ln(1+i)}$$

$V_n = Future\ value$
$V_0 = Present\ value$
$i = Interest\ rate$
$n = Number\ of\ time\ periods$
$ln = natural\ logarithm$

Note: In this formula, we have the addition of a new variable, the natural logarithm (ln). A natural logarithm gives you the time to reach a certain level of growth. It is the opposite of an exponent, which gives you the amount of growth that would occur over a certain amount of time. In this case, we know the amount of growth and are trying to solve for time, so we use the natural logarithm.

Example Exercise F

Let's say that we plan to put $7,000 into a savings account and we want to know how long it will take for it to grow to a value of $15,000 if the annual interest is 5%.To solve our problem, the formula will look like this:

Step 1: $n = \frac{ln\left(\frac{15,000}{7,000}\right)}{ln(1+0.05)}$

Step 2: $n = \frac{ln(2.143)}{ln(1.05)}$

Step 3: $n = \frac{0.7621}{0.0487}$

Answer: $n = 15.65$

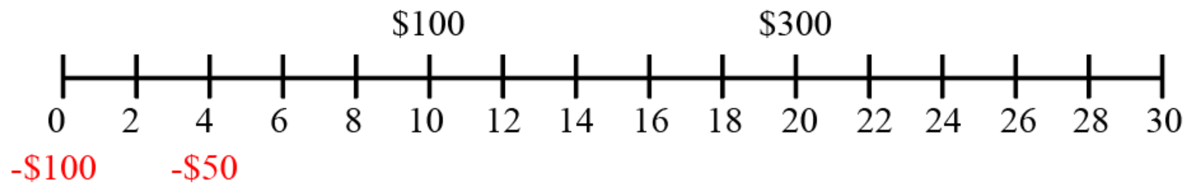
At an annual rate of 5% interest, for our investment to grow from $7,000 to $15,000 would take about 15 and a half years.

Video – Interests Rates and Time Periods
https://vimeo.com/574747749

4 Capital Budgeting

Capital budgeting is a process that an organization or individual undertakes to evaluate different projects or investments. Every project or investment is different because they have different cash flows that occur at different times. A cash flow diagram is a horizontal line that represents time, with costs and revenues reflected with vertical lines when they occur along the timeline (see figure 1). Revenues occur above the timeline and costs occur below the timeline. This helps to convey complex financial data in a visual format. The formulas used in financial mathematics allow the user to convert single or multiple cash flows that will be received at different points in time to one number. We can then use these single numbers to compare and rank different projects and investments. This process is called capital budgeting, discounted cash flow, and/or financial analysis.

Figure 1: Example timeline of cash flows occurring at different points in time



4.1 Financial analysis decision criteria

There are many different types of financial criteria used to assess investment projects. The criteria that will be discussed in this workbook are net present value (NPV), internal rate of return (IRR), cost/benefit (CB) ratio analysis, and land expectation value (LEV).

4.1.1 Net present value

In section three of this workbook, we discussed how to find the present value of a future cash flow. NPV is simply the present value of all the revenues minus present value of all the costs. An investment project is deemed to be acceptable if the NPV is greater than zero. When the NPV is greater than zero, it simply means that the financial return from the project is greater than the discount rate selected for the NPV formula.

4.1.2 Internal rate of return

IRR is a financial criterion that measures the compound interest that is earned by the money that is invested in a project. It is the average rate of capital appreciation during the investment. It is assumed that a project is acceptable if the IRR from the analysis is above a targeted or goal ROR that indicates acceptance. This is sometimes called the hurdle rate because it is the minimum ROR that a project must achieve to be acceptable.

4.1.3 Cost/benefit ratio

CB ratio is a method comparing the costs and benefits of an investment project to determine if it should be implemented. CB analysis involves identifying the present value of all the costs and the present value of all the revenues. Then, the present value of total revenues is divided by the present value of the total costs. This gives you the CB ratio. For an investment project to be acceptable, the CB ratio must be greater than or equal to one. If the CB ratio is less than one, it means that the costs are greater than the benefits or revenues. CB analyses are typically used by government agencies, when multiple project objectives are desired that are not solely focused on financial profitability. In CB analysis, it is common for other social attributes of a project to be included, such as employment, salary generation, and the income distribution effects of an investment project.

4.1.4 Land expectation value

LEV is an estimate of the value of land for a specific purpose. This estimate of value does not contain the cost to purchase the land. It is just an estimate of pursuing a specific activity continuously into the future. In the case of this workbook, it is an estimate of the value of a parcel of land for growing timber. This estimate includes the present values of all costs and revenues that will occur within the specified time period. The estimate also assumes that once the time period of the specific purpose has ended, it will be repeated and again, infinitely.

The formula to calculate LEV uses a formula that has not previous been covered in this workbook. This formula calculates the present value of a perpetual periodic series (see below). When calculating LEV, all the costs and revenues are compounded to what their futures values would be at the end of the time-horizon (harvest rotation age) given the interest rate (net future value). LEV is typically calculated for a hectare basis so that it can be compared to other similar investment projects.

Land expectation value formula

$$LEV = \frac{NFV}{(1+i)^n - 1}$$

$$LEV = Land\ expectation\ value$$
$$NFV = Net\ future\ value = NPV(1+i)^n$$
$$i = Interest\ rate$$
$$n = Number\ of\ time\ periods$$

Video – Net Present Value & Capital Budgeting
https://vimeo.com/574748284

4.2 Selecting the discount rate

Choosing the appropriate discount rate is one of the most important components of a financial analysis. Slight variations in the selected discount rate can affect whether a project is accepted or rejected. The selection of the discount rate primarily reflects the cost of capital. The cost of capital is simply what it cost to borrow the money being used for the project, or the financial return that could be received if the money was invested in an alternative investment. For example, if the money was borrowed from a bank that is charging 7% interest, the 7% interest rate is the cost of capital. Alternatively, if you already had the money and did not need to borrow it, but you could place that money in a savings account that paid 3% interest, the 3% interest rate is the cost of capital. In this case, it is an opportunity cost of 3% for selecting an alternative investment. Alternative names for the discount rate are the alternative rate of return, the guiding rate of return, and the hurdle rate. The hurdle rate refers to a minimum rate that the investment needs to yield to be acceptable.

4.3 Sensitivity analysis

In an investment analysis, risk and uncertainty are always present. The future is never certain and even the best economic forecasts are incapable of considering every variable at play. Risk exists when it is probable that there will be various outcomes to a management decision. Uncertainty exists when the probability distributions of the various outcomes is unknown. Multiple methods have been developed to analyse risk and uncertainty. One of the primary methods is sensitivity analysis. Sensitivity analysis involves individually adjusting key variables to see what the impact is on the selected financial criteria (NPV, IRR, CB, and LEV). Sensitivity analysis is especially important if you are uncertain of the appropriate value for a key variable, and if your selected financial criteria is near the cut-off point that decides whether the project is accepted or rejected.

The most important key variable to include in a sensitivity analysis is the interest rate or discount rate. A small change in the interest rate can have large impacts on the results of the financial criteria when revenues and costs are compounded or discounted over long-time horizons. Other key variables that are commonly included in a sensitivity analysis are the length of the time horizon, the initial costs that happen at the beginning of the time horizon, and the value of the revenues. The length of the time horizon will have a large impact on present and future values. As the time horizon increases, the present value will decrease. Vice-versa, a longer time horizon will result in future values being larger. For example, a forest that takes 50 years to reach a volume appropriate for a timber harvest will have a smaller NPV then a forest that takes 25 years to grow, assuming the per unit value of the timber is the same. This is because the timber revenues received from the 50-year-old forest will be discounted more than the timber revenues received from the 25-year-old forest. In comparison, the initial costs of a forest related investment project, such as site preparation and planting, will receive little or no discounting since they occur in year zero or year one. Thus, the costs and revenues that occur early-on in the time horizon will have a much greater impact on the financial criteria results than costs/revenues that occur towards the end of the time horizon. This is not to say that accuracy in estimating revenues occurring at the end of the time horizon (timber harvest) is not important, it is just to demonstrate that these values will be impacted more by exponential effect of compound interest.

5 Using spreadsheet software for capital budgeting

Spreadsheet software is a useful tool for conducting financial analyses when there are multiple cash flows occurring at different points in time. When designing these financial models, it is important to separate the model assumptions from the actual financial model. The financial model should always reference the spreadsheet cells that contain the model assumptions. The purpose of this separation is for conducting a sensitivity analysis. When the models' assumptions are separated, they can easily be adjusted to assess their impact on the results of the financial analysis.

A spreadsheet example exercise has been developed for this training workshop. This exercise is based on a modelled teak plantation from data collected in Papua New Guinea. The model assumptions are presented in table 2. A link to a Google Sheets template for this exercise is provided below.

Link to Spreadsheet Financial Analysis Template – Teak Plantation

https://docs.google.com/spreadsheets/d/1OA4acGwUjDIxX_9_iUiq-EzAMSg9cXR9/copy

Link to Spreadsheet Financial Analysis (Completed Answers) – Teak Plantation

https://docs.google.com/spreadsheets/d/1-CaMN3ayXsmSocWlKW5nTWiJLCZyTFwj/copy

Table 2: Financial model exercise assumptions for teak plantation

Year	Description	Unit	Assumption Value
	General Assumptions		
	Discount rate	%	10%
	Size of plantation	hectare (ha)	1
	Revenue Assumptions		
	Sawlog value (1st Grade)	PGK/m^3	300.00
	Sawlog value (2nd Grade)	PGK/m^3	150.00
10	Commercial thinning volume (2nd Grade)	m^3/ha	36
15	Commercial thinning volume (2nd Grade)	m^3/ha	46
25	Timber harvest volume (1st Grade)	m^3/ha	140
25	Timber harvest volume (2nd Grade)	m^3/ha	140
	Capital Outlay Assumptions		
0	Seedlings planted	number/ha	625
0	Cost per seedling	PGK	2.00
	Labour Assumptions		
	Labour wage	PGK/hour	3.5
0	Site preparation	hours/ha	80
0	Planting	hours/ha	48
0	Weeding	hours/ha	80
0	Line tending	hours/ha	130
0	Pruning	hours/ha	24
1	Pruning	hours/ha	24
2	Pruning	hours/ha	16
3	Pruning	hours/ha	88
2	Pre-Commercial thinning	hours/ha	150
6	Pre-Commercial thinning	hours/ha	100
10	Commercial thinning	hours/ha	72
15	Commercial thinning	hours/ha	50
25	Timber harvest	hours/ha	120

6 The forest rotation age problem

Selecting the appropriate timber harvest rotation age is one of the most significant decisions made in forest management. This decision will be based on the management objectives of the specific forest stand. If profitability or cost management are objectives, this will have an impact on the selected rotation age. The following video introduces how financial objectives can impact the rotation age of a forest stand.

Video – Optimal Forest Rotation
https://vimeo.com/577820457

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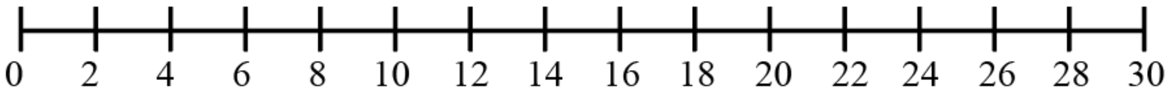
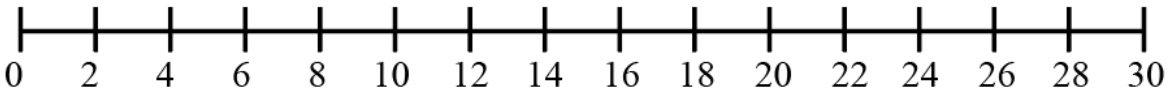
7 Practice problems

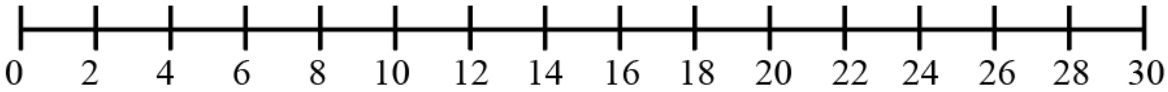
1. The prices currently being received for one cubic meter of Kwila in the Morobe Province are 75 PGK. Due to a decrease in the available Kwila trees, it is expected that the prices are going to increase by 7% per year for the next five years. In five years, what will the expected price of Kwila be?



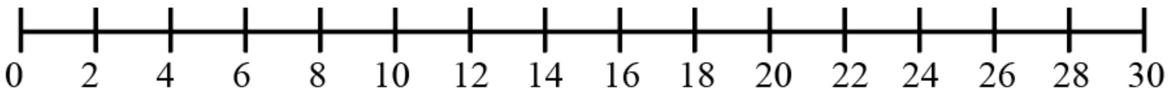
2. A teak plantation manager is considering implementing a pruning treatment. The cost of pruning will be 150 PGK/ha. The teak plantation will be harvested in 15 years. Using a 7% interest rate, how much additional revenue will need to be generated from the timber harvest to cover the cost of the pruning treatment?



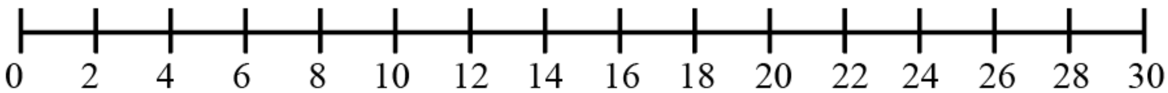
3. You are considering applying an herbicide treatment to release the hoop pine trees at your plantation. Research indicates that the treatment will result in an additional 20 m^3/ha when the trees are harvested at age 45. The trees are currently 10 years old. You estimate that the value of the hoop pine at the time of the harvest will be 150 PGK/m^3. The cost for the applying the herbicide is 200 PGK/ha. Should you implement this treatment?



4. You have a five-hectare teak plantation that is 15 years old. A local sawmiller has just offered you 130,000 PGK to harvest the all the timber. You believe that if you wait to harvest the plantation when it is 25 years old, it will be worth 315,000 PGK. If you sell the timber today, you could invest the money into an interest paying saving account at an interest rate of 7%. Which option would you choose?



5. You are planning to grow eucalyptus trees to sell to a nearby biomass facility. You estimate that it will cost you 2,000 PGK/ha to establish your plantation and that you will receive 8,000 PGK/ha when they are harvested in five years. What is the internal rate of return (IRR) that you will receive for this investment?



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Value Adding Opportunities for Community Timber in Local Sawmills in Lae

Final Report prepared for Objective 3.7 for the mid-term review of ACIAR project FST/2016/153 'Enabling Community Forestry in PNG'
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1 Introduction:

This report responds to project activity 3.7 'Explore value adding opportunities for community timber in local sawmills in Lae.' The methods intended for this activity were;

'In collaboration with the Timber and Forestry Training College (TFTC) and Hamea Enterprises[1], identify local timber processors and their production, products and markets in the Lae/Madang area who would benefit from a revised timber authority (TA) harvest permit and reduced impact logging (RIL) guidelines for small-holders involved in eco-forestry. Undertake a series of harvesting and processing trials, using timber from eco-forestry operations, to facilitate access to value-adding opportunities for the participating communities. Monitor the costs and benefits of these trials.'

Background information on the TA harvest permit

Identifying the key constraints of the TA harvest permit and suggesting opportunities to improve the TA process was the objective for activities 3.1 and 3.2. One of our findings from these research activities was that there is a large informal timber market in PNG made up of forest resource owners (FROs) and small-scale timber producers that chose to operate outside the view and regulations of the government. Participants of the informal market chose to operate there due to constraints of the TA process, and other challenges that exist in the formal timber market. These other challenges include a declining real value of timber royalties and mis-management of the royalty payments. These findings are discussed in detail in our report 'Constraints of the Timber Authority Harvest Permit and Options for Improvement.'

Background information on the harvesting and processing trials

At the time of the writing for report, the harvesting trials have not yet occurred. With the assistance of TFTC, an FRO site has been identified that will be suitable for the harvesting trial. The delay of the trial is the required mechanical maintained of TFTC's Cat 527 dozer/skidder. The quoted cost of the repairs exceeds the allowable project budget allotment. At this time, various alternatives are being considered.

Background information on eco-forestry

Eco-forestry is defined as an ecologically sustainable and economically viable alternative to conventional logging. The key principles of eco-forestry were derived from the 'Sustainable Forest Management' and 'Ecosystem Approach' to forest management principles, which were promulgated from the outputs of the United Nations conference on Environment and Development in Rio de Janeiro in 1992. Beginning in the 1990s, the eco-forestry management model was introduced in PNG by multiple non-government organizations (NGOs). The

[1] Hamea Enterprises is a small-scale wood product manufacturer located in the city of Lae. The founder of Hamea Enterprises is Dr. Eddie Nir, who agreed to assist us with our research.

premise of this management model was that NGOs trained FROs to fell trees on their own land and produce rough-sawn lumber with portable sawmills that was to be exported. To meet the eco-forestry principles, the timber harvests were to be evenly distributed across all species present at the site to maintain the composition and structure of the forest. Research by Scudder et al. (2018) found that the eco-forestry management model ultimately failed at all of the NGO facilitation sites. The leading causes of the failure were that despite the trainings provided by the NGOs, the human capacities of the FROs never reached a level that allowed for the production quality and quantity of lumber desired by the market buyers. In addition, it was found that only four of the tree species (*Dracontomelon dao*, *Intsia bijuga*, *Pometia pinnata*, and *Pterocarpis indicus*) had a rough-sawn lumber sales value per m^3 that was greater than the mean cost of milling per m^3 (i.e. cash outflows from sawmill operations and sawmill labour) (Scudder et al. 2019). The implication of this finding is that the eco-forestry model of an even harvest distribution across all species is not financially viable. If only the most profitable species are harvested there is a risk of ‘high-grading’ or ‘creaming’ of the forest. A review of one of the NGO’s lumber export shipping manifests revealed that almost all the shipments were solely comprised of *Intsia bijuga*, indicating that the true intent of eco-forestry may not have been put into practice.

Background information on the Central Processing Unit (CPU)
There has been an ongoing interest among the PNGFA and ACIAR FST/2012/092 (Enhancing Value Added Wood Processing in Papua New Guinea) in identifying a functioning model for a Central Processing Unit (CPU). The essential role of the proposed CPU is the creation of value-added wood products derived from small-scale timber harvest on FRO lands. One of the objectives of the proposed CPU was that the CPU would undertake the TA application requirements to mitigate the human and financial capital constraints experienced by FROs. At the time of this writing, the CPU is still a research concept in progress. Two of the ACIAR FST/2012/092 project outputs were a market analysis report for the proposed CPU by Smith (2018) and the creation of a business plan for the proposed CPU, which was produced by Yakuma (2017).

The market analysis by Smith (2018), recommends that the CPU focus should be on the housing sector and other small buildings for the PNG market. An additional recommendation by Smith (2018), was to assess the possibility of the CPU manufacturing rotary peeled veneer and/or plywood. Demand for plywood in PNG is increasing within the housing sector. However, this is currently not a core competency of TFTC and an assessment has not been made on if TFTC could feasibly manufacture this type of wood product. The business plan by Yakuma (2017), recommends that the CPU manufacture sawn wood products using logs harvested from a timber authority (TA) harvest permit possessed by TFTC and from rejected export logs from industrial harvest sites. Manufacturing sawn wood products is a core competency that TFTC already possesses, as portable sawmill training is part of their college curriculum. Both the market analysis by Smith (2018) and the business plan by Yakuma (2017), do not identify specific wood products that the CPU should manufacture or the target market to be focused on.

Implications of previous research findings
One of the intended activities for this research was to facilitate value-adding operations with FRO communities. We found that the previous attempts by NGOs to facilitate FRO value-add operations with portable sawmills resulted in financial expenditures in excess of $28 million (2018 USD) over two decades with no lasting outcomes (Scudder et al. 2018). Since these previous attempts at value-add capacity development were not successful, we determined that

it would be more prudent to focus our research on identifying opportunities for improving the financial return that FROs receive from selling their timber. We also found that there are multiple value-add wood product businesses operating in the informal market. This finding indicated that these businesses have already identified a successful operating model. We determined that it would be beneficial to gain an understanding of this existing model and focus our research on opportunities for making improvements to this model. Due to these findings, we revised our intended methods for this research activity.

Our revised methods have been separated into three sub-activities. For the first sub-activity we undertook a value-chain analysis of the informal timber market sector. The objective of this analysis was to gain an understanding of the change in product values at each step of the value-chain and determine if changes could be made to improve financial returns to FROs. The second sub-activity was a production cost analysis of multiple value-add wood products to identify the products with the largest gross profit margins. The intent of this sub-activity was to assist the proposed CPU and other small-scale manufacturing businesses in identifying options for improving profitability. The third sub-activity was a market situation analysis for the products identified in sub-activity two. The purpose of this sub-activity was to assist the proposed CPU and other small-scale manufacturing businesses in identifying strategic market options for the proposed products.

2 Methods:

The methods used to conduct our three sub-activities are described below.

2.1 Value chain analysis of the informal timber market sector

We used a case study methodology to investigate the value chain of the informal market sector[2]. Our data collection included interviews of FROs and small-scale timber producers. We categorized the small-scale timber producers as; sawmill owner only; small-scale manufacturer with no mills; and small-scale manufacturer with mills. The term 'manufacturer' refers to the small-scale timber producer owning wood machining equipment that allowed them to produce value-add wood products; dressed structural lumber; mouldings; and tongue & groove (T&G) flooring. We interviewed a total of 19 informal market sector participants that comprised 23 interviewees (see table 1). These participants were located in and near the cities of Lae and Madang (see figure one). The names of the 19 informal market participants and associated interviewees have been omitted to ensure confidentiality. The questions asked were; where the timber/wood products were sold and to whom; the type of equipment used to harvest the trees and process the timber; the cost of production; and prices received from sales. The interview format was similar for all interviewees. The interviews were primarily conducted by the first author, with participation also provided by the third author and a former research forester of the Tropical Forestry and People Research Centre. Hand-written notes were taken by the three interviewers during all interviews. The length of the interviews varied between 30 minutes and one hour. At least one staff member of PNGFA or TFTC was present at all the interviews to provide their post-interview perspective to the interviewers.

We compiled the interview data into tables with Microsoft Excel software. For each stage of the value chain we organized the sale prices by species/products. We then averaged the sales prices to identify the change in product values at each step of the value chain. The value chain stages that we used were; log standing on the stump; rough-sawn lumber at the harvest site;

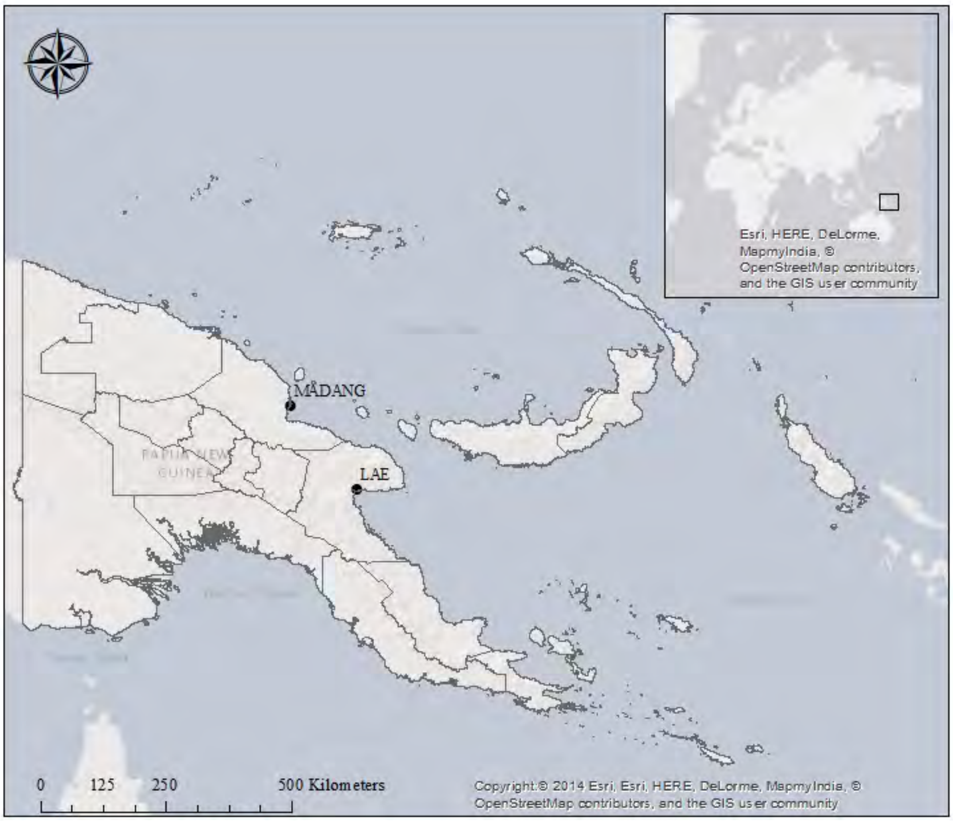
[2] The value chain analysis of the informal market sector was a sub-set of a larger case study on the informal market sector (Scudder et al. 2019a).

rough-sawn lumber delivered to a manufacturing business; and finished value-add product for sale at the mill. We selected four wood products to asses at each value chain stage, which were; T&G flooring (*Intsia bijuga* 95 x 20 mm); treated architrave moulding (mixed hardwoods 70 x 20 mm); treated structural lumber house post (*Vitex cofassus* 150 x 150 mm); and treated weatherboard (mixed softwoods[3] 145 x 20 mm). These products were selected because we were told that they were commonly produced by small-scale manufacturers in the informal market.

Table 1: Descriptions and number of interviewees

Informal market participants	Participants	Interviewees
Forest Resource Owner (No mills)	2	3
Forest Resource Owner (With mills)	4	5
Sawmill owner only	6	6
Small-scale manufacturing business (No mills)	1	1
Small-scale manufacturing business (With mills)	6	8
Total	19	23

Figure 1: Location of research sites



[3] We were told that these species were mixed tropical deciduous species that had softer wood than most tropical hardwoods. They were not conifers.

2.2 Production cost analysis of value-add wood products

We conducted in depth interviews with identified experts of small-scale wood product processing in Lae. The interviewees were comprised of seven professors/teachers from TFTC and two small-scale wood product manufacturer business owners. The interviews were conducted by the first author and a PNGFA employee. Hand-written notes were taken by both interviewers during all interviews. The length of the interviews varied between 30 minutes and 2 hours. Production cost data from interviewees of the value chain analysis activity was included when available. The purpose of these interviews was to identify the average production costs and gross profit margins for a series of value-add wood products at each stage of the value chain. The value-add wood products we selected were; treated D-mould (mixed hardwoods 20 x 10 mm); treated architrave moulding (mixed hardwoods 70 x 20 mm); T&G wood flooring (*Intsia bijuga* 95 x 20 mm); treated weatherboard (mixed softwoods 145 x 20 mm); and six dimensions of treated dressed mixed hardwood structural lumber. The dimensions of the dressed structural lumber were 50 x 50 mm, 75 x 50 mm, 100 x 50 mm, 150 x 25 mm, 150 x 50 mm, and 150 x 150 mm. The value-chain stages that we assessed the production costs were; milling of rough-sawn lumber with portable sawmill in forest; transporting the lumber to a manufacturing business; grading and sorting the lumber to be air-dried; machining the lumber; and chemical treatment if applicable.

We compiled our interview data into tables with Microsoft Excel software. For each stage of production, we organized the production costs by species/products. We then averaged the costs for each category to derive an average cost for each production stage. For each product, we calculated an expected gross profit per m^3 of finished product and the associated gross profit margin.

2.3 Market situation analysis

A market situation analysis is comprised of four steps (Marshall and Johnston 2009); an analysis of the macro-external environment; an analysis of the competitive environment; an analysis of the internal environment of the organization; and a SWOT (strengths, weaknesses, opportunities, and threats) analysis, which summarizes the findings of the first three steps. The purpose of the macro-external environment and competitive environment analysis is to identify the existing opportunities and threats of the market. The purpose of the internal environment analysis is to identify the strengths and weaknesses of the organization that would be operating the proposed CPU.

The macro-external environment analysis includes five sub-steps. These are; the political and legal rules, laws, and norms that impact operating behaviour; demographic trends among consumers; technologies used in the industry; overall economic conditions and the impact that they will have on an industry; and the natural environment which includes sustainability issues (Marshall and Johnston 2009). We assessed these five sub-steps through a review of the available technical reports on these subjects and informal interviews with PNGFA and TFTC staff. In addition, we forecasted new housing construction for the Morobe and Eastern Highlands Provinces to estimate the potential size of the geographic market. This forecast was developed with data collected from the PNG 2011 census report by the PNG National Statistical Office (PNGNSO) (2013b), which provided data on population by district, annual population growth rates by province, and average number of people per dwelling by province. Additional data used for the forecast was sourced from a household and income expenditure survey by PNGNSO (2013a), which indicated that only 20.8% of homes in the Morobe Province and 24% of homes in the Eastern Highlands provinces are non-traditional dwelling[4].

The analysis of the competitive environment includes five sub-steps. These are; the threat of new entrants (assessment of barriers to entry); rivalry among existing firms; the threat of substitute products; the bargaining power of buyers; and the bargaining power of suppliers. These sub-steps were assessed through informal interviews with PNGFA and TFTC staff, as well as additional field interview research conducted by project partners at PNGFA and TFTC.

The internal environment analysis includes four sub-steps. These are; analysis of the firm structure and systems; the culture of the organization; the current leadership; and the organization's resources. The purpose of this analysis is to assess how these sub-categories include a customer-centric focus as a core value of the organization. At the time of this report there is no existing CPU organization. It is currently unknown who would operate the CPU, with potential suggestions being TFTC, the PNGFA, and a private business. This report has assumed that TFTC will be the operator of the CPU, and the strengths and weaknesses section of the SWOT analysis are based on TFTC's capabilities.

Figure 2: SWOT analysis template

	Opportunities (external, positive)	**Threats** (external, negative)
Strengths (internal, positive)	**Strength-Opportunity strategies** Which of the company's strengths can be used to maximize the opportunities you identified?	**Strength-Threats strategies** How can you use the company's strengths to minimize the threats you identified?
Weaknesses (internal, negative)	**Weakness-Opportunity strategies** What action(s) can you take to minimize the company's weaknesses using the opportunities you identified?	**Weakness-Threats strategies** How can you minimize the company's weaknesses to avoid the threats you identified?

3 Results:

3.1 Value chain analysis

Our estimates of the values for our four selected wood products at the four value chain stages of the value chain are discussed below.

Stumpage value is typically defined as the residual value of the logs after subtracting logging costs and transportation costs from the price paid for the logs by a sawmill. The stumpage value is typically the payment that a landowner can expect to receive for their timber. When we conducted our interviews with FROs and the small-scale timber producers we found that payments to FROs for their timber are typically not calculated on a log volume basis. The most common payment arrangement was referred to as the '2 for 1 agreement.' The 2 for 1

[4] The term permanent housing refers to homes that are constructed from lumber, concrete, steel, and other materials. Most of homes in PNG are traditional homes, which are constructed from bush materials. While some of the traditional homes may incorporate manufactured wood products in their design, these materials are typically recycled from some other previous use.

agreement allocated two thirds of the milled lumber to the portable mill owner and one third of the milled lumber to the FRO, who typically was given the option of selling their portion of the lumber to the sawmill owner at an agreed rate. From the average of these set rates and assuming a lumber recovery rate of 50%, we estimated the value of the ‘logs standing on the stump’ for our four selected wood products. In some cases, the FROs owned or had access to a portable sawmill but were not able to transport the milled lumber to a manufacturing business. In these situations, the manufacturer would arrange the transportation but would provide a different payment price than if the lumber had been delivered by the FRO. The finished product price refers to the sales prices per m^3 of product. These products are typically sold at rates per lineal meter, which we have converted back to m^3 or ease of comparison. These product values by value chain stage are presented in table 2.

Table 2: Value of wood products are various value chain stages (Kina per m^3 of log/lumber)

Value-chain stage	T&G flooring	Architrave moulding	Structural lumber house post	Weatherboard
Log standing on the stump[1]	77	63	63	30
Rough-sawn lumber at harvest site[2]	500	450	450	450
Rough-sawn lumber delivered to mill[2]	1,058	750	750	750
Finished product located at mill[2]	4,702	3,352	2,133	2,667

[1] refers to log value (Kina per m^3).
[2] refers to lumber value (Kina per m^3)

3.2 Production cost analysis

Our estimates of the average production costs for our 10 selected products at the selected production stages are presented in table 3. We found that the value-add wood products with the highest expected profit margins to be: D-mould (88%); T&G flooring (82%); weatherboard (72%) and architrave (71%). While D-mould had the largest profit margin, this product has the smallest dimensions of the products assessed (20 x 10 mm) and is typically manufactured from the leftover scrap of larger products. All the structural lumber products assessed had a gross profit margin of 62%.

Table 3: Average value-add production costs and gross profit margins for selected products (Kina per m^3 of lumber product)

Value-add products	Timber and sawmilling cost				Transport cost	Value-add manufacturing cost				Gross profit analysis			
	Payment to FROs	Labour	Oil/Fuel	Total cost		Grading & Sorting	Machining	Chem. Treat.	Total cost	Grand total cost	Sales price	Gross profit	Gross profit margin
D-mould[1]	126	488[6]	290[6]	758	271	23	117	1	140	1,315	9,807	8,492	87%
Architrave[2]	126	366[7]	218[7]	654	271	23	17	1	40	1,020	3,352	2,332	70%
T&G flooring[3]	154	244	145	543	271	18	9	-	27	841	4,702	3,861	82%
Weatherboard[4]	60	244	145	449	271	14	7	1	21	741	2,667	1,926	72%
Structural lumber[5]													
50 x 50	126	244	145	515	271	18	6	1	25	810	2,140	1,330	62%
75 x 50	126	244	145	515	271	18	4	1	23	808	2,140	1,332	62%
100 x 50	126	244	145	515	271	18	3	1	22	807	2,140	1,333	62%
150 x 25	126	244	145	515	271	14	4	1	18	804	2,140	1,336	62%
150 x 50	126	244	145	515	271	14	2	1	16	802	2,133	1,331	62%
150 x 150	126	244	145	515	271	14	1	1	15	801	2,133	1,332	62%

[1] Mixed hardwoods, 20 x 10 mm.
[2] Mixed hardwoods, 70 x 20 mm.
[3] *Intsia bijuga*, 95 x 20 mm.
[4] Mixed softwoods, 145 x 20 mm.
[5] Mixed hardwoods, multiple dimensions mm.
[6] We assumed D-mould would be the result of re-sawing and doubled the labour and oil/fuel costs.
[7] We assumed that architrave would often be the result of re-sawing and increased the labour and oil/fuel costs by a factor of 1.5.

3.3 Market situation analysis

3.3.1 Macro-external environment

We found that most of the small-scale timber market operators exist in an informal market that operates outside the view or regulation of the government. The reason this market is referred to as ‘informal’ is because these participants are not applying for and receiving the required TA harvest permit. The PNGFA currently does not have the resources to enforce this regulation and limits their involvement of TA enforcement to lumber exports. The current political environment of the TA results in three potential threats; the export market is not available to non-TA operators; the government could change their policies and begin policing the informal market; and if an organization does pursue a TA, they will have larger operating costs relative to other informal market participants.

Transportation within PNG is difficult and expensive. Most of the roads are in poor condition, which dramatically reduces the speed of transport. Furthermore, there is not a highway system that connects all the cities within PNG. For example, traveling from Lae to Port Moresby is only by possible by airplane or boat. The market analysis by Smith (2018), recognized that Lae is PNG’s largest port city and capable of accessing Port Moresby, which is the largest permanent housing market within PNG. However, participating in a market that requires ocean transport will add additional complexity to the CPU business. We suggest that the CPU initially focus on nearby markets that can be reached through road transport. These markets are the city of Lae, the rest of the Morobe Province, and the Eastern Highlands Province.

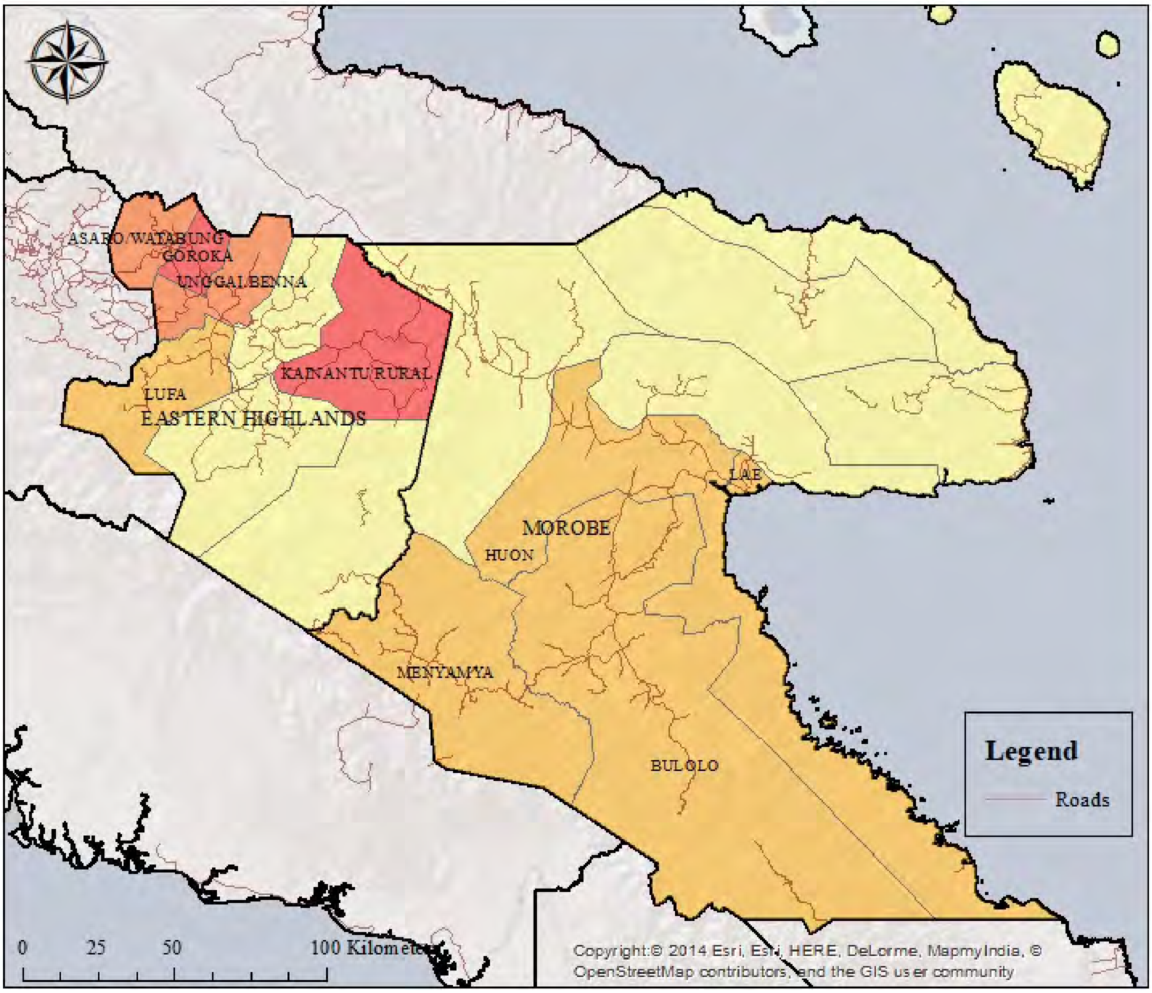
Our housing forecast identified two geographic markets that have highest potential new housing demand in the Moroboe and Eastern Highlands Provinces (see Table 4 and Figure 3). The geographic market with highest potential demand was in the Eastern Highlands and comprised of the Goroka, Kainantu, Unggai/Benna, Asaro/Watabung, and Lufa districts. The second identified geographic market was made up of the Lae, Bulolo, Huon Gulf, and Menyamya districts in the Morobe Province. We identified four customer categories that purchase value-add wood products within these provinces. The two primary customers are hardware supply retailers and construction companies. The customer categories are independent carpenters and the general public.

The manufacturing technology in use by small-scale manufacturers is predominantly made up of equipment with low economies of scale and outdated machinery. The use of portable sawmills will typically never reach a level of productivity that can be achieved through conventional logging and modern fixed site saw mills. The primary machining equipment that we have viewed are various moulding machines and planers (thicknessers). Almost all the machining equipment we viewed appeared to be several decades old. An implication of using out of date machinery is that it may be difficult to produce products with a level of quality made by competitors using more modern equipment. The industrial-scale wood processing sector in PNG is comprised of 28 saw mills, one plywood mill, one veneer mill, and eight furniture manufacturers (PNGFIA 2010, PNGDL 2015). In 2016, PNG’s wood processing sector produced approximately 82,000 m^3 of sawn wood, 29,000 m^3 of plywood, and 62,800 m^3 of veneer (ITTO 2017).

Table 4: Housing demand forecast for the Morobe and Eastern Highlands Provinces

Province	District	2019	2020	2021	2022	2023
Morobe	Bulolo	169	174	180	185	191
	Huon Gulf	126	129	133	137	141
	Menyamya	117	120	123	127	130
	Nawae	61	62	64	66	68
	Lae (Urban)	35	36	36	37	37
	Lae (Rural)	136	143	150	157	165
	Markham	88	91	93	96	98
	Total	732	755	780	805	831
Eastern Highlands	Kainantu	335	347	361	374	388
	Henganofi	52	52	53	54	54
	Unggai/Benna	252	264	277	291	305
	Goroka	334	349	364	380	397
	Asaro/Watabung	228	239	250	262	275
	Lufa	152	157	163	168	174
	Okapa	81	83	84	86	87
	Total	1,434	1,492	1,552	1,615	1,680
Grand total		2,166	2,247	2,332	2,419	2,511

Figure 3: Comparison of housing demand by district in the Morobe and Eastern Highlands



Note: Greatest demand is in the red coloured districts, followed by the dark orange, light orange, and yellow coloured districts.

The primary macro-economic factor we identified that could have an impact on the proposed CPU is a government proposed log export ban. Currently, approximately 90% of logs harvested in the formal market are exported. There is an interest within the PNG government in reducing the volume of log exports and increasing the downstream processing of wood products. To facilitate this, a log export ban has been proposed to occur in 2020. If the proposed ban did occur, it is possible that the small-scale wood product market would be flooded with cheap logs and wood products, making it difficult for the proposed CPU to compete. We were told that this is not the first time a log export ban has been proposed by the government, with past proposals occurring in 2000 and 2010. Multiple interviewees told us that the proposed 2020 log export ban is unlikely to happen for two reasons. The first reason is that the timber concession given to the logging industry are multi-year contracts with the government, which would be violated by the ban. The second reason is the government is currently struggling to source enough revenue to cover its operating costs and is dependent on the revenues generated from log export duties.

Environmental sustainability is always a consideration that must be assessed within the forest products industry. We found that the species *Intsia bijuga* is one of the most highly sought-after timber species in both the formal and informal markets. Its primary uses are for house posts, beams, structural lumber and furniture. The popularity of this species is due to extremely dense heartwood (641-961 kg/m3), limited shrinkage insect repellent properties, and the rich dark colour of the heartwood (Thaman et al. 2006). Due to its high popularity, *Intsia bijuga* has been recognized as being seriously threated from overexploitation in the South Pacific (Thaman et al. 2006). This species is also a shade-tolerant and slow growing species that can take 75 to 80 years to reach maturity (Thaman et al. 2006). If this species continues to be over-harvested in PNG, it is likely to be replaced by less valuable early successional pioneer species. We were told by several small-scale manufacturers that sourcing *Intsia bijuga* timber is getting harder and they continually have to travel greater distances to find it.

3.3.2 Competitive environment

An analysis of the threat of new entrants is primarily an assessment of how strong the barriers of entry are to an industry sector. In the small-scale wood product manufacturing sector, the primary barrier is the access to capital for the purchase of machining equipment. While the cost of this equipment is small relative to many types of modern manufacturing equipment, it is beyond the financial reach of most small-scale forest industry participants. Furthermore, since most participants operate within the informal market, they are often viewed as illegal operations and not able to qualify for bank financing.

Currently, we have not been able to assess the extent of rivalry among the existing small-scale wood product manufacturers. Since many of these businesses operate within the informal market, they are not readily identifiable through online searches. Further research by in-country project partners is needed before a thorough assessment can be completed.

We found that there is a threat of substitutes to value-add wood products. Several of the interviewees told us that there is a growing interest in substitutes to wood products such as steel, cement, and plastics. The tropical climate in PNG can result in wood products quickly deteriorating if they are not properly treated. We were told that the interest in substitutes is due to some manufacturers not properly treating their products, or not treating them at all.

Currently, we have not been able to assess the bargaining power of the value-add wood product buyers (hardware supply retailers and construction companies). Further research by in-country project partners is needed before a thorough assessment can be completed.

We have determined that the bargaining power of the timber suppliers (FROs) is minimal. The FROs are primarily ‘price takers’ that have limited knowledge of market demand or the market value of timber species at the various stages of the value chain. We found this also to be true of the majority of saw millers that act as middlemen between FROs and the manufacturing businesses. The small-scale manufacturing businesses currently have bargaining stronghold over the other small-scale market participants.

3.3.3 Internal environment

The internal environment assessment will need to be completed by the future entrepreneurial team of the proposed CPU. The assessment should include; analysis of the firm structure and systems; the culture of the organization; the current leadership; and the organization’s resources. The purpose of this analysis is to assess how these sub-categories include a customer-centric focus as a core value of the organization.

3.3.4 SWOT analysis

We have identified the strengths, weaknesses, opportunities and threats, which are listed below.

Strengths

- TFTC owns all or most of the equipment needed to implement the proposed CPU. This equipment includes; portable sawmills, chain saws, dump truck, chemical-pressure-treatment facility, and wood working machines/tools; moulding machine, table saw, planer/thicknesser, sanders, and basic carpentry tools.
- TFTC has an existing manufacturing site, allowing them to conduct milling, lumber drying processes, value-add processing, and finished product storage.
- The faculty at TFTC train students in the use of wood product manufacturing and award ‘Year 1’ certificates in solid wood processing. Thus, they have expert level experience themselves.
- TFTC already manufactures value-add wood products for sale, thus giving them experience in conducting business transactions.

Weaknesses

- TFTC is first and foremost, a school/training facility. There is not enough equipment to operate a full-time business and to continue to use the equipment for educational purposes.
- Most of the equipment is greater than 40 years old, with much wear. There is a need for replacing this equipment with modern machinery with advanced technologies.
- The faculty at TFTC are the expert equipment operators, but they are first and foremost teachers. Using the faculty to operate the equipment for the CPU will result in a conflict of interest with TFTC’s current core competency – teaching.
- There is the possibility that the salaries paid to the faculty are higher than a standard wood product manufacturing business would pay its equipment operators. If this is the

case, the CPU's operating costs would be higher than its competitors, which would result in reduced profits relative to the competitors.

- TFTC has experience in producing value-add wood products for sale, but it has never operated as a private business solely dependent on sales revenues. Conducting business transactions (exchanging wood products for money) does not guarantee that the business management experience necessary for a maintain profitable business currently exists in the organization.

Opportunities

- Improving chemical treatment procedures for wood products, combined with an appropriate marketing campaign to educate customers about the benefits of the treated products. In addition, changes in the chemicals used can be done to fall in line with the international wood treatment and preservation standards.
- Improving the quality of wood products by sourcing modern machining equipment.
- Improving the quality of wood products by improving the air-drying procedures and/or researching options for low-cost kiln drying (solar kilns).
- Improving the quality of wood products by introducing more stringent grading procedures.
- Utilizing timber species that are easier to source for specific products, combined with an appropriate marketing campaign to educate customers. For example, *Pometia pinnata* is a timber species that is a suitable replacement for *Intsia bijuga* for T&G flooring, it is prevalent throughout PNG forests, and an earlier successional tree species that is more likely to experience natural regeneration.

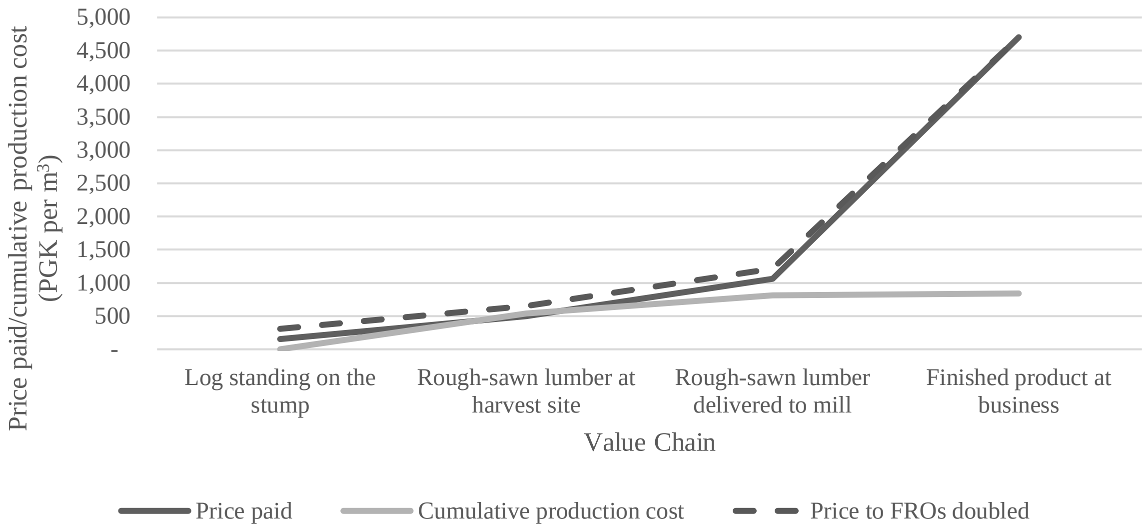
Threats

- Permanent housing demand is low due to most people not having the financial means to purchase/build a permanent home.
- Industrial-scale sawmills can produce lower-cost products due to economies of scale.
- Shipping costs in PNG are high.

4 Discussion:

We found that in the current small-scale timber sector, the manufacturing businesses are capturing most of the timber values. Our analysis of the production costs and gross profit margins revealed that there is an opportunity for FROs to receive a greater return for their timber. For example, we found that if payments to FROs were doubled for timber used to make architrave, T&G flooring, and weatherboard, the gross profit margins only declined by 2-4%. As the gross profit margins after this adjustment are 66-79%, there appears to be a more than adequate gross profit margin remaining for businesses to make a fair profit. We provide an example of the prices paid and cumulative production costs at each stage of the value chain for *Intsia bijuga* T&G flooring in figure 4.

Figure 4: Comparison of prices paid and cumulative production cost for T&G flooring



We recognize that the high gross profit margins are a necessary incentive for entrepreneurs to take the risk of establishing a business and for recovering the costs of capital equipment purchases. However, we believe that these gross profit margins are much higher than similar businesses in other countries and that this is due the limited availability of market information to all participants. One of the economic principles of the free market system is that market participants will always make rational decisions that are in their best interest when they have complete access to market information. We found that in PNG, the only participants that seem to be aware of the market values are the manufacturing businesses. FROs and most of the saw millers have not made rational decisions that are in their best interest because they do not have access to market information. To mitigate this challenge, we suggest that there be an increase in extension forestry. We have also made this recommendation in our reports for activities 3.1 and 3.2. An increase in the number of extensions foresters will allow for a greater level market information dissemination. This would increase the bargaining power of the FROs and saw millers and likely raise the prices that they receive for their timber.

We determined that the primary niche products that the proposed CPU should focus on are T&G wood flooring (made from *Pometia pinnata*, and *Intsia bijuga*), weatherboard (made from mixed softwoods, and architrave made from mixed hardwoods. We found that these products had the largest profit margins and require a larger volume of use per housing unit relative to D-mould. Structural lumber products that are in demand should still be produced, but we recommend that the cutting patterns for milling the logs focus on producing flooring, weatherboard, and architrave pieces. In addition, focus on these value-add products can act as a hedge against the larger sawmills that are able to produce rough-sawn lumber products at lower costs.

We suggest that the CPU differentiate itself from competitors by striving to produce the highest quality T&G flooring and weatherboard within the target market. Opportunities for improving product quality can be achieved with the purchase of modern machining equipment, improved drying and grading standards, and improved chemical treatment procedures. We recommend that further research be conducted to identify the specific product attributes desired by the target market related to these quality improvement opportunities. We also recommend that further research be conducted to identify the service attributes desired by the target market. Some examples of service attributes are; installation instructions included with the product; installation training; product delivery; prices; payment options; and sales reps being available.

In addition to the products suggested above, we also suggest that further research be conducted into identifying additional market opportunities for the wood product residues/waste materials. One product option that has been identified for the short-length timbers/offcut materials is foldable, portable and do-it-yourself (DIY) furniture such as student desks small tables and stools (Ozarska et al. 2019). Research by Ozarska et al. (2019), in collaboration with TFTC, completed a DIY furniture pilot project utilizing previously unwanted short-length timbers. Further research should be conducted on the potential market opportunities for these products. Firewood is an additional product that has been identified as an option for utilizing the wood slabs, and lumber offcuts (Yakuma 2017). The residue product options for sawdust and shavings produced by the moulding machine and planer/thicknesser should also be explored. These residues could potentially be used for charcoal production and/or sold to charcoal producers. By identifying product lines for these wood residues, the CPU revenue streams can be increased, and wood product waste can be reduced.

We suggest that the CPU target market be businesses in Lae that are within a close proximity to the CPU. While we were able to identify districts in the Eastern Highlands that have high demand for new permanent housing (Goroka, Kainantu, Unggai/Benna, Asaro/Watabung, and Lufa districts), it is recommended that these be a secondary market focus since these sites will require greater marketing costs. In addition, product shipping costs will also be lower if customers are in the city of Lae or nearby rural areas.

We recommend that an in-depth operational plan be developed for the CPU. The purpose of this plan is to identify strategies for mitigating the weaknesses recognized in the SWOT analysis. This plan would explore the required employees, daily activities, and estimated daily operational costs. The purpose of this assessment would be to identify expected manufacturing outputs and costs at the weekly, monthly, and annual levels. A business plan produced for the proposed CPU by Yakuma (2017) has provided a good initial estimate of operational expenses and outputs. It is also suggested that this operational plan discuss the relationship between the proposed CPU and TFTC to outline several items; who is in charge of management decisions of the CPU, how the CPU finances will be distinct from TFTC's finances, the role of TFTC faculty, and if/how TFTC's existing manufacturing equipment and property will be used by the CPU.

It is possible that the CPU may not be operated by TFTC but may be established nearby in Lae. In this case, TFTC would be able to deliver training and collaboration with the CPU operating entity and the PNGFA.

5 Conclusion

We had three research objectives for this analysis; 1) gain an understanding the change in product values at each step of the value-chain and determine if changes could be made to improve financial returns to FROs; 2) complete a production cost analysis of multiple value-add wood products to identify the products with the largest gross profit margins; and 3) conduct a market situation analysis to assist the proposed CPU and other small-scale manufacturing businesses in identifying strategic market options for the proposed wood products. We found that the small-scale manufacturing businesses have captured the bulk of the timber value with a minimal portion being captured by the FROs. We surmised that this is due to a lack of market information dissemination and suggest that an increase in extension forestry could assist in improving the education and timber sale bargaining power of FROs. We found that the value-add products that have the largest profit margin potential for the proposed CPU are T&G flooring, weatherboard, and architrave. We suggest that the CPU focus on becoming a manufacturing quality leader with these identified products. Our market situation analysis indicated that the geographic market locations with the best potential for the CPU are in selected districts in the in Lae within close proximity to the CPU. Secondary markets that can be pursued later are in the Eastern Highlands Province.

For further research, we recommend that other geographical markets also be assessed for development of a CPU entity. It may be that there are locations where there is already a strong demand for value-added wood products. Developing multiple CPUs in the various regions of PNG could be helpful in improving small-scale forestry operations throughout the country. In addition, further research is also needed in identifying opportunities for the government to aid in linking the proposed CPUs to landowners interested in selling their timber. This would support CPUs in securing the raw timber required for conducting their value-add operations.

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