Australian Government
Australian Centre for International Agricultural Research

Raising trees and livelihoods

Experiences of integrating trees into smallholder farming systems

ACIAR MONOGRAPH 221

Raising trees and livelihoods

Experiences of integrating trees into smallholder farming systems

Editors
Digby Race and Gib Wettenhall

Australian Centre for International Agricultural Research
and The University of the South Pacific

ACIAR

2024

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. ACIAR operates as part of Australia's international development assistance program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and international researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

The Chief Executive Officer of ACIAR reports directly to the Australian Government Minister for Foreign Affairs. ACIAR operates solely on budget appropriation from Australia's Official Development Assistance (ODA).

Where trade names are used this constitutes neither endorsement of nor discrimination against any product by ACIAR.

ACIAR MONOGRAPH SERIES

This series contains the results of original research supported by ACIAR, or material deemed relevant to ACIAR research and development objectives. Publications in the series are available as hard copy, in limited numbers, and online from the ACIAR website at **aciar.gov.au**

Digby Race and Gib Wettenhall (Eds) 2024, *Raising trees and livelihoods: Experiences of integrating trees into smallholder farming systems*, ACIAR Monograph No. 221, Australian Centre for International Agricultural Research, Canberra.

ACIAR Monograph No. 221 (MN221)

ISSN 1031-8194 (print)
ISSN 1447-090X (PDF)
ISBN 978-1-923261-03-7 (print)
ISBN 978-1-923261-04-4 (PDF)

Technical editing and proofreading by Mary O'Callaghan
Design by whitefox.com.au
Printing by CanPrint Communications

Foreword

While the world's population becomes increasingly urbanised, smallholders, who typically manage fewer than 2 hectares, remain important land managers and produce about one-third of the world's food.

Smallholders face a world of compounding risks due to many factors, including increased frequency and intensity of severe weather events due to climate change, the degradation of soils and water supplies due to increasing land development and urbanisation, changing demographics and labour availability in rural communities, and unpredictable markets and supply chains. These factors interplay with complex social and political events that also affect smallholders and their communities.

Traditional farming practices of smallholders have commonly included the management of trees on farms for multiple purposes, including for food, fibre and shelter. While the integration of agriculture and forestry is an ancient practice, it also has a modern relevance.

Agroforestry has the potential to provide much needed food security and nutrition, as well as wood and other products. Combined, these benefits improve the livelihoods of farming families and the resilience of communities. Though individual operations are often small scale, at a national level, the aggregate impact of smallholders practicing agroforestry can play an important role in expanding the supply base for commercial timber industries, reforesting degraded landscapes and contributing to climate change mitigation measures.

The Australian Centre for International Agricultural Research (ACIAR) is mandated under the ACIAR Act (1982) to work with partners across the Indo-Pacific region to generate the knowledge and technologies that underpin improvements in agricultural productivity, sustainability and food systems resilience. We do this by funding, brokering and managing research partnerships for the benefit of partner countries and Australia.

ACIAR has supported a meaningful and impactful program of forestry research since the establishment of the agency in 1982. Agroforestry has been an important component of that program and farming women and men have been actively involved in agroforestry research from the outset, which has yielded locally relevant results and opportunities.

This book draws together a decade of learnings and knowledge from more than 15 ACIAR-supported projects, synthesising the latest science on purposeful tree management, farming systems and value adding by smallholders in the world's tropical regions. It captures the complexity and richness of smallholder forestry practice and illustrates the benefits for landscapes and livelihoods.

Reflecting the strong partnership model that underpins ACIAR, this book brings together the work of almost 100 authors who have deep experience and knowledge of smallholder forestry systems in the tropical zones of the Pacific, Asia, Africa and Central America.

ACIAR is proud to support the production of this book, which will enhance the understanding of policymakers, research program managers, project staff and community leaders about potential livelihood outcomes from investments in smallholder forestry research.

Wendy Umberger
Chief Executive Officer, ACIAR

Acknowledgements

The source of inspiration for publishing this book is the ingenuity and tireless work of thousands of smallholders, their organisational partners and other supporters, as they adapt, innovate and develop agroforestry in a myriad of ways to suit their livelihoods, local markets and wider landscapes. As discussed throughout this book, the conditions and context for agroforestry are dynamic, so our collective knowledge, skills and understanding also needs to evolve. I know that by sharing this book widely we are contributing to the understanding of agroforestry's important role in our contemporary landscapes and livelihoods.

My early discussions with Nora Devoe of the Australian Centre for Agricultural Research (ACIAR) informed the scope of this book, which I warmly appreciated. The support provided by ACIAR and The University of the South Pacific is gratefully acknowledged.

My sincere thanks to the more than 90 contributing authors who carefully integrated and synthesised many years of their research (extending to several decades for most authors) so that their work is easily understood by readers from outside academia. Of course, all the authors have worked closely with many smallholders, organisations and other partners – I thank you all for contributing to the collective knowledge presented in this book.

All authors are listed in Appendix 1.

I am grateful for the patient and skilful editing by Gib Wettenhall and, in the later stages of production, Mary O'Callaghan, who copyedited and proofread this book. I thank them both for their commitment to ensure the book's high quality.

I also wish to acknowledge the tragic loss of co-author, colleague and friend Dr Tony Page of the University of the Sunshine Coast, who died unexpectedly during the final stages of preparing this book. Tony greatly impressed those he worked with throughout the Oceania region over many years, with his practical research, his insightful knowledge, and his warm interest in rural communities and how they could use trees to improve their livelihoods.

Digby Race
Editor

Contents

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ACTIV	Alternative Communities Trade in Vanuatu
ANU	Australian National University
APSIM	Agricultural Production Systems sIMulator
ARuPA	*Aliansi Relawan untuk Penyelamatan Alam* (Volunteers Alliance for Saving Nature)
ASMINDO	*Asosiasi Pengusaha Mebel Indonesia* (Indonesian Furniture Industry and Handicraft Association)
BCR	benefit:cost ratio
BLU	*Badan Layanan Umum* (a public service agency within the Indonesian Ministry of Forestry
BPS	*Badan Pusat Statistik* (Statistics Indonesia)
CBCF	community-based commercial forestry
CBFM	Community-Based Forest Management (a program in the Philippines)
CFUG	community forest user group (Nepal)
CIFOR	Center for International Forestry Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DAFO	district agriculture and forestry office (Lao PDR)
DBH	diameter at breast height
DENR	Department of Environment and Natural Resources (Indonesia)
DKP	*Deklarasi Kesesuaian Pemasok* (supplier's declaration of conformity – Indonesia)
DoF	Department of Forests (Vanuatu)
EAA	equivalent annual annuity
ENB	East New Britain (Papua New Guinea)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field school
FJD	Fijian dollar
FLR	forest landscape restoration
FOERDIA	Forestry and Environmental Research, Development and Innovation Agency (Government of Indonesia)
FORSPA	Forest Research Support Programme for Asia and the Pacific
FSC	Forest Stewardship Council
HTR	*Hutan Tanaman Rakyat* (community plantation forest – Indonesia)
ICRAF	International Council for Research in Agroforestry (now World Agroforestry)
IPCC	Intergovernmental Panel on Climate Change

IRR	internal rate of return
LAK	Lao kip (currency)
LER	land equivalent ratio
LEV	land expectation value
LPG	liquified petroleum gas
MIS	managed investment scheme
MOLESS	Ministry of Labour, Employment and Social Security (Nepal)
mSMEs	micro-, small- and medium-sized enterprises
MTG	Master TreeGrower
NARI	National Agricultural Research Institute (Papua New Guinea)
NGO	non-government organisation
NPV	net present value
NTFP	non-timber forest product
ODA	Official Development Assistance
PDR	People's Democratic Republic (Lao)
PGK	Papua New Guinean kina (currency)
PGM	peer group mentoring
PNG	Papua New Guinea
PO	people's organisation
PPAP	Productive Partnerships in Agriculture Project
RAIL	Ramu Agri-Industries Ltd
RIRDC	Rural Industries Research and Development Corporation
RLI	relative light intensity
RMV	Ramu–Markham Valley (Papua New Guinea)
RRC	rural resource centre
SDG	Sustainable Development Goal
SME	small-to-medium-sized enterprise
SPRIG	South Pacific Regional Initiative on Forest Genetic Resources
SVJ	sengon, vanilla and ginger
SVJT	sengon, vanilla, ginger and small taro
SVLK	*Sistem Verifikasi Legalitas dan Kelestarian* (Indonesia's timber legality and sustainability verification system)
SVT	sengon, vanilla and small taro
UNEP	United Nations Environment Programme
UniSC	University of the Sunshine Coast
VPA	voluntary partnership agreement
VSU	Visayas State University

Chapter 1

Overview of smallholders' livelihoods and forestry

Digby Race

The importance and scale of smallholders

Smallholders find themselves working on the frontline of some of the world's most pressing issues, confronting, for instance, severe weather events due to climate change, the degradation of soils and water supplies, declining food security, and dealing with unpredictable markets and supply chains.

They need to triage how to respond to sustain their livelihoods – a delicate balance between surviving in the short term and sustaining their natural assets in the longer term. Often responding to local opportunities and risks, their pragmatic approach to land use integrates annual crops, cash crops, livestock and trees. In doing so, they must carefully manage their diverse livelihoods to optimise farm production and household resources. An increasing proportion of smallholders have no choice but to look elsewhere to diversify and earn extra household income, working, for example, as labourers and self-employed entrepreneurs (Race et al. 2021). Better management of their trees at home offers them another means of diversification. Pursuing agroforestry can provide much needed food security and nutrition, as well as wood and other fibre, which together can vastly improve the livelihoods of smallholder farm families. This is the message at the heart of this book.

While the world's population is becoming increasingly urbanised, smallholders (small-scale farmers who manage fewer than 2 hectares (ha)) remain important land managers – an estimated 480 million smallholders manage 84% of farm enterprises and 12% of the world's agricultural land (Lowder, Skoet and Raney 2016). A recent estimate by the Food and Agriculture Organization (FAO) is that smallholders '… generate a gross annual income of up to US$1.29 trillion' (FAO 2022:vii). Most smallholders manage mixed farming systems that diversify beyond commodity agriculture, yet they live with fluctuating environmental conditions, markets and policies. Typically, little is known about how their livelihood strategies are changing to meet opportunities and pressures (Gautam and Andersen 2016; Vadjunec et al. 2016). While smallholders in lower-income countries are vital to their countries' food security, there is concern that they are not adapting at the scale needed to maintain food production (Taylor et al. 2016; Thorton et al. 2018). Furthermore, there is increasing evidence that smallholders are pursuing opportunities beyond agriculture, such as in China (He et al. 2020) and India (Reddy et al. 2014), leading to the transformation of local economies, rural landscapes and society. Yet, how smallholders manage the land matters at the local and wider scales. At a landscape scale, the dynamics of land-use change are typically complex, multidimensional and non-linear, making it hard to accurately project change based on current trends (Wilson 2007; Meyfroidt et al. 2018; Riggs et al. 2021).

Despite global uncertainty, indeed perhaps because of it, the world's smallholders remain vital food producers at both the local and global levels, producing about a third of the world's food (Ricciardi et al. 2018). Yet, they are more than simply food producers – they are entrepreneurs (adapting and trialling new technology), they are custodians (applying and sharing local knowledge and wisdom); they are guardians (preserving local genetic resources and varieties); and they are optimists, often planting trees and managing forests that will benefit others long after they have gone. The complex and varying narrative defining their lives says that some will prosper while others will struggle. Sometimes their future and fortune rest precariously in the hands of others, or, as some might say, their fate lies in the lap of the gods.

While the integration of agriculture and forestry is an ancient practice, it has a modern relevance. It seeks to achieve multiple goals at the local level (for example, optimising land use, diversifying farm income) and at the global level (for example, helping to reforest farming landscapes, aiming to improve productivity and sustainability) (Taylor et al. 2016).

Research and development projects, together with local adaptation and innovation, continue to ensure agroforestry is greater than the sum of its parts, illustrating that raising trees and livelihoods can be complementary. The FAO (2022:xvi) recently stated that, 'Agroforestry systems tend to be more resilient than conventional agriculture to environmental shocks and the effects of climate change'. When research knowledge is translated and applied locally, and then used to inform policies and programs, it can lead to more purposeful design, greater synergy between components, and more productive and sustained outcomes. By connecting smallholders with experience and knowledge from outside their social networks, opportunities often arise to see common practices or conventional wisdom through another lens. At the very least, an outside perspective encourages smallholders to reflect on what they do and prompts them to ask themselves if there is another way, a better way, to achieve their objectives.

The influence of research may not always be apparent, particularly if there is little observable change in land use. Yet, the experience and knowledge from outsiders, especially if derived from proven research and practical experience, can still enhance the livelihoods of smallholders. Well-applied research can confirm their current ideas and practices, increase their knowledge and skill in silviculture, give them the skills to be more precise, improve their understanding of market dynamics, and create stronger links with market brokers and processors. Overall, research should build their confidence in knowing how best to invest their farm and household resources. The 'options by context' approach, recently developed in Africa, is a helpful example of how to localise support for smallholders who want to farm with trees (Crossland et al. 2022). In summary, agroforestry works best when smallholders are empowered to design, manage, harvest and replant according to their objectives, without being tightly constrained by outside interests.

Figure 1-1: **Agroforestry works best when designed and managed by confident and informed smallholders.**

Credit: Digby Race

Small-scale forestry

Smallholders are small-scale farmers whose traditional farming practices have commonly included some management of trees or forest for multiple purposes (Race and Wettenhall 2016), typically by planting timber species on plots of fewer than 2 ha (Erbaugh et al. 2017). Despite their small-scale individual operations, in aggregate smallholders can play a key role in a country's forest policy, particularly in terms of expanding the supply base for the commercial timber industry and reforesting degraded landscapes.

For example, the Indonesian forestry sector includes significant areas of smallholder agroforestry and commercial plantations known as the peoples' forests or *hutan rakyat* (Royo and Wells 2012) or as farmers' privately-owned forests (Fujiwara et al. 2018)[1]. On community private lands alone, smallholders produce timber on at least 1.5 million ha in Java. However, growing trees as a component of agroforestry does not necessarily translate into future prosperity for smallholders, as they typically face considerable economic, institutional and regulatory barriers when seeking to commercialise forest products (Maryudi et al. 2017; Nambiar 2019). For example, Africa produces 75% of the world's cocoa, but captures less than 10% of the total market value of the commodity. Even the revenue received at the local level for this global commodity can fluctuate widely, disrupting local economies and livelihoods (Minang et al. 2021).

During Indonesia's democratisation process, beginning in the late-1990s, the government recognised that encouraging smallholders to become actively involved in forestry was a way to resolve the long history of conflict over land tenure between the state and local and Indigenous communities, as well as between the state and private companies (Purnomo and Anand 2014). In its reform of forest policy, the government looked to the potential of community-based forest management, with a key role to be played by smallholders. The purpose of this reform was to give local communities greater access to state-owned forests and resources and, therefore, reduce poverty among forest-dependent people (Lindayati 2002; Li 2007; Safitri 2010; Urano 2013). It is unclear whether commercial forestry contributes much to the income of smallholders in Indonesia, or favours wealthy smallholders over poor smallholders.

Even at a broader level, the contribution smallholders make to economic development is uncertain because of the inherent difficulty of capturing accurate data (Midgley et al. 2017; Carle et al. 2020). A weak grasp of the local context can lead to poorly designed or implemented projects that can inadvertently ignore the economic inequity and social structures that exist throughout the world. Indeed, pioneering research many decades earlier found that, due to a naive understanding of smallholders' livelihoods, tree planting projects can make some farmers poorer (Hobley 1990). It is estimated that smallholders, local communities and Indigenous peoples own or manage about half of the world's farm and forest landscapes (4.35 billion ha) (FAO 2022:vii), yet they remain some of the world's poorest people. Listening to those with the loudest voices, visiting farms closest to the roadside, sharing a meal with those who are available, may give us a biased or distorted picture of how best to support local people's aspirations for improving their livelihoods. For example, while farming with trees appears to have much to offer poor farmers, they are often busy, illiterate and remotely located with insecure land tenure – and many are marginalised women (Galabuzi et al. 2021). Even for tree products that have historically been harvested and sold by women and are increasing in commercial value, opportunistic outsiders and unfair institutional arrangements can create new barriers to women sustaining their livelihoods (Cronkleton et al. 2021; FAO 2022).

1 Earlier studies describe privately-owned forests as forest resources consisting of home gardens (*pekarangan*), dry land (*tegalan*) and woodlots (*alas* or *kitren*) (Fujiwara et al. 2018).

Using far more explicitly people-centred terms, such as ‘community forestry’ or ‘social forestry’, can still lead to failure in achieving the social benefits widely anticipated by large-scale adoption of integrated trees and agriculture (Gilmour and Fisher 1991). Complex equations and confounding factors (for example, biophysical conditions, fluctuating markets, unsupportive regulations) mean that when smallholders merely plant a few trees, the benefits may be years away and enjoyed mostly by others (Malla 2000; Chhetri 2009; Cedamon et al. 2019). Despite a vast investment over many decades – in expertise, finance, labour and technology – the vision of the world’s smallholders leading prosperous lives that are supported by sustainable tree farming and yielding products that receive fair prices still appears unfulfilled, notwithstanding many impressive local examples (Gilmour 2016).

Agroforestry defined

The guiding definition of agroforestry adopted within this book is the purposeful integration of trees into farming systems. This definition reflects agroforestry when practised by landholders to diversify their enterprises and safeguard their assets. Agroforestry can act as a pathway to optimising overall production and reducing risks. Given that the nature of agroforestry is about seeking short-term benefits and long-term returns, it could be favoured more by high-income households with a greater ‘buffer capacity’ and resilience than by low-income households, but this is uncertain (Ifejika Speranza, Wiseman and Rist 2014). In some ways, agroforestry reduces the capacity of smallholders to quickly develop an alternate land use because planting trees on farmland is a commitment to a particular land use for the life of the trees (that is, the medium-to-long term, or at least 5 years). Yet, growing trees is typically a much less-intensive crop to manage compared to common annual agricultural crops (for example, cassava, rice), so it affords opportunities for smallholders to allocate their time elsewhere, leading to enterprise diversification and, potentially, greater overall income. Already, agroforestry is practised on at least 45 million ha, with an increasing trend worldwide (FAO 2022:xii). After more than 40 years of research and development by World Agroforestry (formerly the International Council for Research in Agroforestry, ICRAF) and its partners, unravelling the evidence of agroforestry’s complexity is revealing its appeal and benefits to a wide range of smallholders and landscapes across the world.

Successfully optimising the spatial and temporal synergies of combining different trees, annual crops and/or livestock on a relatively small area of land (plots are commonly smaller than 2 hectares) draws on immense experience and skill, and requires thoughtful planning of a farm’s long-term calendar. It also requires considered thought among household members about their aspirations and questions about their likely future, such as should we intensify or diversify enterprises, what major expenses do we anticipate, will it increase our risk or build our resilience, will our children want to be farmers? Agroforestry is a common approach by smallholders to achieve multiple objectives. Creating a new ‘blended’ knowledge, fusing deep traditional knowledge and contemporary science, could harness a mix of ‘hard’ and ‘soft’ technical innovations (Roshetko et al. 2022). Such a fusion of knowledge might create a bright horizon for smallholders and the evolving practice of agroforestry, and in doing so, form a positive link between development and the environment.

About this publication

This book aims to capture the complexity and richness of smallholder forestry and illustrate how and why it works best – for both landscapes and livelihoods. Its more than 50 authors bring a combined deep experience of smallholder forestry across Asia, Africa, Central America and the South Pacific, and share research results, key findings and their understanding of how to optimise smallholder agroforestry in the world's tropical zone (Figure 1-2).

The information presented in this book reflects the growth cycle of planted forests – species selection, tree breeding, tree establishment, management; and along the value chain – measuring and selling, harvesting and hauling, processing and manufacturing. The experience shared here by the authors highlights the challenges for anyone investing in smallholder forestry, but particularly for risk-averse smallholders with little finance, land and time in reserve if things do not go according to plan.

The authors draw on their research and development expertise to blend science with the practice of smallholder forestry, accompanied by vignettes of practical examples. In so doing, they provide a holistic and realistic analysis of what works for smallholders and what the potential of agroforestry might herald if it were to become more widely adopted.

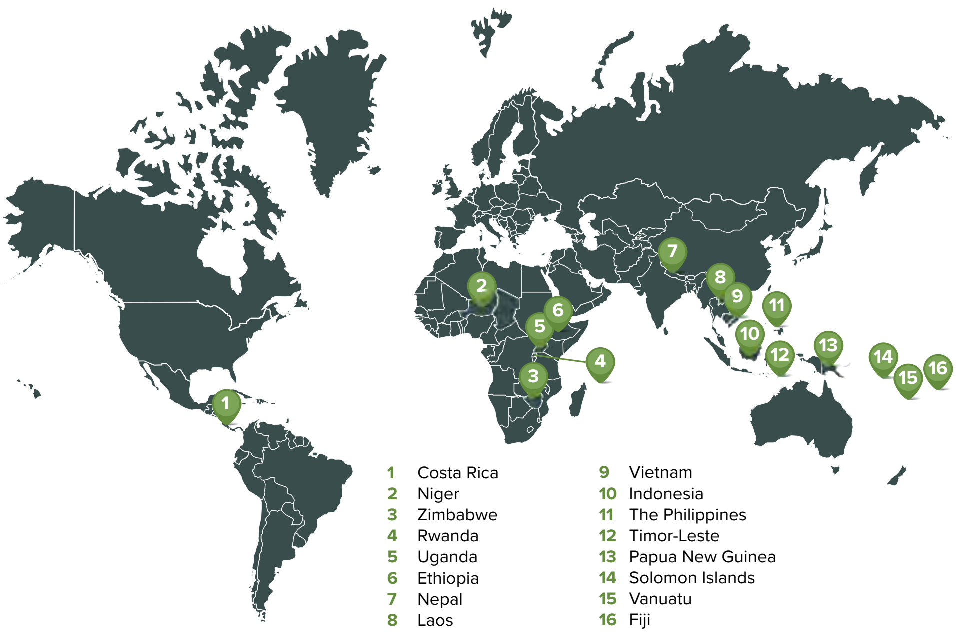

Figure 1-2: **Map showing locations referred to in the book**

Topics covered by the authors

Smallholders in the South Pacific typically face several challenges to achieving the full potential of agroforestry – a long distance to export markets, inefficient economies of scale, small domestic markets, a limited natural resource and production base, and vulnerability to external shocks and natural disasters. These challenges in turn can deter smallholders from investing in agricultural opportunities that lead to export diversification. There are, however, opportunities for growing a range of indigenous perennial tree crops and agroforestry crops that have both domestic market and export potential. In **chapter 2**, Page et al. explain that domesticating underused crops that use existing wild germplasm is an important development opportunity for Melanesia. They say that forest crops could generate much greater economic benefits – both local and national – than continued harvesting from already depleted native forests. The focus of their discussion is based on their experiences in Melanesian countries including Fiji, Vanuatu, Solomon Islands and Papua New Guinea.

Optimising agroforestry, particularly when seeking to initiate landscape-scale projects involving many farmers and their communities, takes more than just selecting the right species. Ensuring projects address the interests of local people is a key aspect in implementing the principles of large-scale reafforestation projects, yet this aspect is often overlooked or given cursory attention. To discuss this important aspect, Wiset et al. draw on their in-depth work in the Philippines and Papua New Guinea in **chapter 3**. They explain how they used landscape visualisation tools in 2 case studies – one in the Eastern Visayas region of the Philippines and the other in Ramu–Markham Valley in Papua New Guinea – to explore the kind of landscape local people wanted to see in the future and why they prioritised those landscape scenarios. Their research revealed that local communities preferred restoring degraded lands with a mixed planting of several species, often on just a small-scale and at a time when they can easily manage the work. Over time these small plantings aggregate across the landscape.

Figure 1-3: **Agroforestry has the potential to provide multiple products for subsistence use and commercial markets.**

Credit: Digby Race

They also found that men and women preferred different species and locations for growing trees, highlighting the importance of taking gender perspectives and roles into account (Wiset et al. 2022). As with any agroforestry system, people can have different perspectives of success, but what is most important is that a project is framed around the farmer's goals and their vision of success. Ultimately, it will be the farmer's actions that determine whether agroforestry is fit for purpose or another failed project with options prescribed by outside experts. To reach back to Robert Chambers seminal work in the 1970s and 1980s (Chambers 1979; Chambers et al. 1989), we need agroforestry that puts 'farmers first'.

In most parts of the world, today's smallholders are managing farmland that holds a deep legacy from the many generations of farmers who came before. Their ancestors tilled the earth, improved soil fertility, tended vital crops, planted tree crops and harvested the fruits of their labour. Over millennia, they forged an inextricable link between farming and livelihoods. This long cycle created a rich knowledge based on local experiences and practices, often supplemented with existential meaning from divine sources. In recent generations, however, smallholders have experienced extraordinary change in their lives which has disrupted the earlier rhythm of their traditional farming and livelihoods. Such disruptions include intervention by central governments, the voracious interests of corporate entities, a creeping connection to the cash economy and, now, the severe impacts of climate change. In combination, these cascading changes are creating a dilemma for smallholders about what knowledge and practice to take forward and what to discard. It is perhaps only in hindsight that we learn that every new idea or innovation may not have taken people with them into prosperous and sustainable livelihoods.

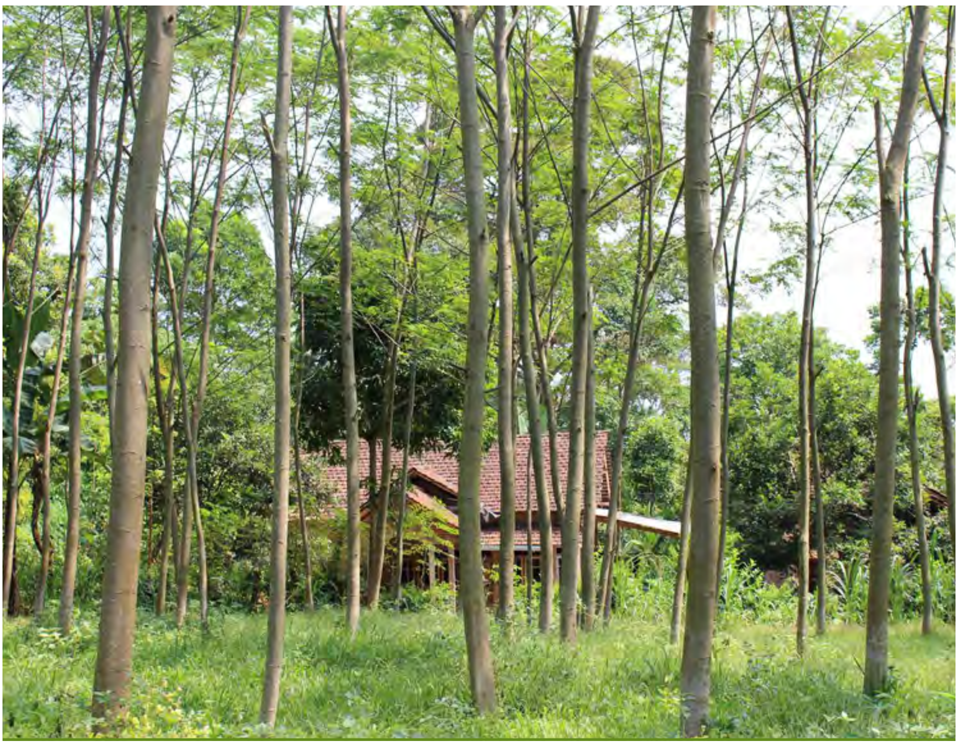

Figure 1-4: Agroforestry can help buffer the livelihoods of smallholders against multiple pressures.
Credit: Digby Race

In **chapter 4**, Mienmany et al. go back to a region in northern Laos where in the 1980s and 1990s teak was widely promoted by the government among farmers. Sensing this as a great opportunity to acquire land, most farmers viewed teak as a 'green bank' requiring minimal inputs as trees grew, and able to be harvested as needed at any time. As value chains emerged, they became heavily reliant on local traders and small-to-medium-sized enterprises, which focused on meeting the demands of neighbouring countries for unprocessed logs and low-value markets – an outcome that had not been foreseen. As a result, the Lao PDR government has introduced regulatory measures intended to protect natural forests and improve enterprise compliance, with new policies aimed at developing domestic processing, accessing new markets and increasing value retention. These new policies have, however, failed to account for smallholders and their key interests and instead created a 'Pandora's box' of complexity and unintended consequences. Mienmany et al. do a great job of untangling the complex cause-and-effect of evolving forest policy in northern Laos, offering valuable insights for policymakers and program managers elsewhere.

The policy context is neither simple nor static, even for the simple concept of encouraging farmers to plant trees – after all, how hard can it be! The valuable insights for Lao PDR policymakers are further confirmed by experiences from Costa Rica and Vietnam, where, as explained by Lo et al. in **chapter 5,** deforestation and human population have grown massively since the middle of the 20th century. Various approaches have been taken to encourage smallholder farmers to establish trees on their farms for both environmental and commercial purposes. For example, in Costa Rica during the 1980s an international program offered incentives to farmers to plant a variety of mainly exotic tree species on farms, with varying success. Also, in Vietnam since the late-1980s there has been a general movement away from government-managed forests towards community-managed forests and private plantations grown by smallholders. As part of this push, more than 2 million hectares of Australian *Acacia* species have been planted for short-term production of woodchips and small sawlogs. The authors explore the biophysical, socioeconomic and policy challenges in Costa Rica and Vietnam when encouraging viable smallholder forestry, and offer advice on developing successful smallholder forestry.

To optimise agroforestry, a strong and iterative link between policy and practice is required. After absorbing the lessons for policymakers seeking to nurture smallholder forestry, we shift focus to the practices that support optimal agroforestry, such as silviculture (that is, tree management). In **chapter 6**, Dieters and Pachas discuss silvicultural approaches that they have developed from many years of research in Laos. These approaches aim to ensure that recommendations are easy to understand and adopt by smallholders and incorporate into their overall farm activities. In many countries, thinning and pruning of planted trees is often seen as wasteful, so smallholders can be reluctant to follow silvicultural recommendations that do not appear to match their idea of harvesting only mature trees. Smallholders have historically used the age of a tree and its height, and spacing with neighbouring trees, to inform their silviculture. After many years of working with smallholders in Laos and other countries, Dieters and Pachas observed that while smallholders have a relatively small number of trees, they are often time-poor and struggle to meet all the labour requirements of farming, seeing active management of trees as a low priority. Yet, smallholders will regularly visit their trees if they have an accompanying companion crop or if the trees are located on their way to do some other farm activity. Also, many smallholders gain comfort from the soothing experience of sitting under the shade of trees they have cared for, and enjoying the ensuing biodiversity. Based on these observations, Dieters and Pachas suggest smallholders follow a silvicultural approach that treats thinning and pruning as continuous activities. This incremental approach, where the tree grower does a little bit regularly, may ultimately achieve the desired goal of optimising spacing and pruning for individual trees.

It should come as no surprise that most national governments have some agenda to provide support to smallholders, either directly or indirectly. After all, smallholders play a crucial role in managing vast areas of natural resources and contributing to food security for billions of people, while adapting to unpredictable and extreme weather and precariously juggling self-sufficiency and commercial markets for their livelihoods. In the archipelago nation of Indonesia, citizens living on more than 10,000 islands offer a rich tapestry of experiences, lessons and possibilities for smallholder forestry. Is it possible to achieve the triple goals of prosperous smallholders, agroforestry across farmed landscapes and vibrant local industries based on sustainable forestry? In **chapter 7**, Race et al. navigate the dynamic policy environment that has characterised Indonesia's forestry and rural development sectors since the mid-1990s to see what has emerged in terms of smallholder forestry. This chapter gives an overview of the historical role of smallholder forestry in Indonesia along with the recent interest and support by government, in the context of the spread of democracy across Indonesia since the late 1990s with the political and social transformation of *reformasi*. More recently, the social forestry agenda in Indonesia has promoted a range of schemes that have the combined goal of reducing deforestation, expanding the supply of commercial timber and encouraging smallholders to develop tree plantations as a new enterprise to reduce rural poverty. Some schemes have met with more success than others.

The authors explore the vibrant industry that has led to the popular option of growing sengon (also known as albizia in other countries) by smallholders in central Java, and the associated value chain that has developed over the past decade. While the Indonesian government's effort to curb the illegal harvest and trade in timber led to the development of Indonesia's timber legality and sustainability verification system, *Sistem Verifikasi Legalitas Kelestarian* (SVLK), the scheme has not had the desired outcome of making 'certified' timber more valuable and thereby further stimulating the market for sustainable forestry. Instead, the complexity and cost of the verification process has overshadowed any advantages of SVLK, discouraging some smallholders from investing more in the commercial forestry sector. Even the use of the much more widely known international certification by the Forest Stewardship Council has not always led to the intended increase in demand and greater payments to smallholders for their trees.

Figure 1-5: Smallholders are responsive to local markets.
Credit: Digby Race

Figure 1-6: **The flourishing *phinisi* boat industry in South Sulawesi, Indonesia, continues to use centuries-old construction methods.**

Credit: Gib Wettenhall

As a contrast with the recent emergence of the sengon industry, particularly for smallholders in Java, the authors are captivated by the many centuries-old *phinisi* boat-building industry that is still flourishing in Bulukumba, South Sulawesi. Having reliable vessels for trading valuable cargo between the thousands of islands that comprise Indonesia remains vital, so perhaps it is not so surprising that the *phinisi* industry is still flourishing. Underpinning this industry is the supply of specialist timber from smallholders, with each *phinisi* boat constructed from a variety of native timbers, all carefully selected to exacting specifications of age-old designs. The resulting high demand for a consistent set of timber species has enabled local smallholders to focus their tree growing on catering for an industry they trust and understand.

As mentioned, farming families are facing extraordinary challenges and change – dilemmas and opportunities of a nature that previous generations did not encounter. High in the Himalaya of Nepal, such change is acutely illustrated. **Chapter 8** presents recent research by KC et al. who discuss how and why profound change is occurring in the Middle Hills region, which has led to very different farms and forests compared to just a few decades ago. Over recent decades, the increasing outmigration of young people, especially men, to cities within and outside Nepal has led to the feminisation of rural communities, where women have become responsible for managing farms and forests while continuing to fulfil their family responsibilities and other community work. The authors have found that farming in this region now tends to be concentrated on farmland near human settlements, while less productive farmland located further away from settlements lies fallow. These fallow sites have proven ideal for natural regeneration of woody vegetation and planted trees. Moreover, women and elderly family members are moving towards low-input, less-intensive farming practices with fewer livestock, less intercropping and fewer crop rotations. Consumption of forest products (for example, firewood, fodder and timber) sourced from community forests has also decreased over time, leading to less-intensive forest management. Nature is regenerating the once-barren Middle Hills of the Himalaya and wildlife is returning.

While some authors have focused on the details of small areas of farmland and forest, others have drawn on their experiences of working at a larger scale – even across multiple countries simultaneously. In **chapter 9**, Muthuri et al. discuss their vital work with farmers in Ethiopia, Rwanda and Uganda. Over 110 million people in these 3 countries depend upon smallholder farming practised across 25 million hectares. Smallholders generally focus on subsistence farming, using low levels of external inputs and depending on rainfall rather than irrigation. With limited market access, most rural households are resource poor, food insecure, and vulnerable to the severe impacts of climate change. This situation is compounded by an increasing population (3% per year across the region) and an increased demand for food, water and energy, coupled with declining farm productivity, over-exploitation of trees in agricultural landscapes, and deforestation.

The authors' research is seeking to improve food security and smallholder livelihoods through the widespread adoption of appropriate, locally adapted agroforestry. They discuss how their research and development has accelerated the adoption of new technologies by farmers aiming to better manage trees on their farms. They are also promoting new marketing strategies and creating awareness of financial options that enhance tree-based value chains. Their experience speaks of a bottom-up or farmer-first approach in which the farmers harness local knowledge to determine locally suitable agroforestry options. This approach has led governments to shift priorities from promoting planting of vast monocultures of a single tree species to the pursuit of broader options to improve the food security of smallholders. A critical and positive outcome of their work has seen the government of Ethiopia elevate agroforestry as a directorate in the newly established Ministry of Environment and Forests. In Rwanda, the government has increased its support of tree growing by private investors and smallholder farmers, as a means of creating a green economy. The private sector, for instance, is involved in tree planting, building nurseries and producing seedlings. And in Uganda, the government is also actively supporting the integration of trees in farming systems.

Tackling the twin challenges of rural poverty and deforestation is a common theme throughout the world's tropical regions and, consequently, a common thread throughout this book. As with most tropical countries, there is huge potential to tackle rural poverty in much of Indonesia through developing smallholder timber and non-timber production that is more productive and profitable. Combining tree planting with the management of non-timber species has proven an important part of farmers' livelihood strategies, but yields are generally low. Sudomo et al. explain in **chapter 10** the opportunities to integrate fit-for-purpose timber and non-timber species to improve livelihoods – even among poor smallholders with few resources – in arid regions of the Nusa Tenggara islands and Gunungkidul in central Java, Indonesia. The authors discuss several case studies of agroforestry developed in these areas, including traditional agroforestry with candlenut, the integration of coffee and other species in a community forest, and using teak to provide essential shade for tuber crops.

Enabling small-scale primary producers to gain a larger share of commercial markets through agroforestry can create profound change for farming families and their communities. In **chapter 11**, Wallace et al. explain that as much as 80% of people in the South Pacific are smallholders with farms comprised of mixed species or agroforestry systems but with little access to distant markets. Processing and adding value can stabilise products, increase their shelf life and enhance market access, especially if processing is done locally. However, a market-driven approach is needed to identify opportunities for value-added products. Moreover, a well-functioning value chain is regarded as critical to business competitiveness and long-term sustainability. The authors' transdisciplinary research identified opportunities in the fruit, nut and honey industries, along with options for adding value and small-scale food processing.

They explain how new value-added agroforestry products were developed with local processors in Vanuatu and Solomon Islands. Training in adding value was provided to participants (mostly women) in Fiji, Vanuatu and Solomon Islands, and the results demonstrated that small-scale food processing and value adding could improve food security and the livelihoods of smallholders in a range of South Pacific countries. The authors provide several examples, such as in Solomon Islands where, after training, women were selling value-added nuts for about 3 times the price of raw products. In Fiji, 48 women undertook an intensive 6-week workshop, at the end of which more than half of them engaged in commercial sales of chutneys and jams. Disruptions to the economy caused by the COVID-19 pandemic further highlighted the need for more value-added local food to improve food security. In Fiji, trading food and bartering processed local food were vital when many people lost their main employment.

In the accompanying **chapter 12**, Wallace et al. discuss the huge potential of nut trees in agroforestry systems to improve livelihoods in developing countries. Currently, only 5 nut species make up 90% of world trade, even though global demand for and consumption of nuts has doubled over the past decade. While many indigenous nut species have been domesticated in traditional agroforestry systems, they are yet to be commercialised. The authors discuss *Canarium indicum* (galip nut) as one indigenous agroforestry tree with enormous potential. It provides nuts with high nutritional value, along with timber and shade for crops. In Papua New Guinea (PNG), where the species is culturally significant, coastal communities have traditionally processed this nut for thousands of years. Over 2,000 smallholders are now participating in the emerging *Canarium* industry in PNG, which is already improving their livelihoods.

Figure 1-7: **Complex agroforestry systems can provide vital medical and nutritional supplies for households.**

As smallholders are expected to manage agroforestry and forests for decades, working closely with them should be a central element of any policy and program that seeks to harness the energy and ingenuity of farmers to meet the desperate need of arresting tropical deforestation. Providing valuable lessons from more than 20 years of observing and working with farmers who want to grow trees, Rowan Reid eloquently illustrates in **chapter 13** the farmer-first paradigm sagely advocated by others in rural development. Reid has applied this paradigm in his training of smallholders, so that they design their own agroforestry in a way and on a scale that suits them. In doing so, they become 'masters' of their trees. Reid discusses how he developed the Master TreeGrower (MTG) training course in the mid-1990s to extend the knowledge of small-scale tree growers by providing information about species, markets, technologies, tree growth (and the impacts of soils and climate), tree measurement and silviculture. MTG courses offer the additional benefit of establishing networks for participants to communicate with key people in industry, government and the research community.

In contrast to some more orthodox reafforestation programs, the MTG course does not advocate (or subsidise) a particular tree species, product, planting design or management practice. Rather, it stresses the importance of farmers making their own decisions as to what practices might be appropriate to their situation. Reid has leveraged the growing number of smallholders who have participated in the MTG training, encouraging those most confident to share their knowledge and skills with interested neighbours. In other words, MTG skills and knowledge are being more widely spread by farmers mentoring other farmers about agroforestry. Reid has taken the MTG course from Indonesia, Timor-Leste and Vanuatu to farmers on the other side of the world in the African countries of Ethiopia, Niger, Uganda and Zimbabwe. He provides evidence, based on multiple evaluations, of the value of the course for expanding the adoption of agroforestry and improving the outcomes for farming communities and their rural landscapes.

Consistent with other authors in this book, Fisher et al. explain in **chapter 14** that non-government organisations and aid projects aimed at improving livelihoods through small-scale forestry or agroforestry initiatives often do so by promoting and supporting specific packages and models. It is assumed that by providing the 'right' models, they will be widely adopted by smallholders. A common experience, however, is that these packages are often rejected or adapted and modified by farmers. Experience shows that not all farmers want the same package, nor are there universally suited packages to the diverse circumstances of all farmers, even among farmers living in the same village. The authors look at the underlying models of small-scale forestry and agroforestry used in research and extension that lead to a common approach. They recommend an alternative approach based on action learning with smallholders and their wider communities. Their views are based on research conducted in PNG, which found that, for smallholder tree-based interventions for commercial purposes, several aspects need to be considered – the farmer's capacity, the farmer's appetite for risk, the availability of markets, and the labour and capital requirements of the proposed interventions.

Another commercialisation option for smallholders interested in agroforestry is through partnerships with processors, either directly (for example, outgrower schemes) or via a market agent. When formalised through a contract, smallholder–industry partnerships can lead to a consistent supply (quality and volume) on a large scale. However, such commercial efficiency often undermines the potential of smallholder forestry to generate benefits beyond the parameters of the contract. In **chapter 15**, Keenan draws on several case studies in different settings in the wider Asia-Pacific region to discuss the types of smallholder–industry partnerships for forestry; the benefits, disadvantages and risks; how best to integrate multiple objectives for different outcomes; and the policy environment that might make these partnerships work.

Figure 1-8: **Smallholders negotiate the demands of commercial markets with maintaining the local environment.**

Credit: Digby Race

After travelling the world vicariously through each compelling chapter, this book completes its journey in **chapter 16**, where the essential knowledge and wisdom acquired from this book is distilled. Each chapter brings its own unique context and lessons, and each author shares a story much greater than their originally defined research project. In aggregate, the authors share a deep understanding about the varied livelihoods of smallholders and their operating context. They show how agroforestry might best be optimised on farmland in a way that reflects the commercial context, wherever that may be in the world's tropics. This book seeks to capture the essence of the authors' knowledge and faithfully communicate it in a way that speaks to many – smallholders, community leaders, rural development specialists, policymakers, program staff and researchers exploring the multiple disciplines that comprise agroforestry.

Read this book as you will – in short bursts to glean ideas from specific projects, or as a continuous thought-provoking journey. Share it with colleagues and friends. Try some of the approaches or incorporate new ideas in the design of your next project. If you are encouraged or inspired by what you read here, please reach out and connect with the authors – let them know what you appreciated in their writing or share something about your own experience of agroforestry. After all, we will all learn more by adding to the collective pool of knowledge, honing our navigational skills along the varied pathways leading to what we hope will prove to be a more prosperous and resilient future for the hundreds of millions of smallholders.

References

Carle JB, Duval A and Ashford A (2020) 'The future of planted forests', *International Forestry Review*, 22(1):65–80.

Cedamon ED, Nuberg I, Mulia R, Lusiana B, Subedi YR and Shrestha KK (2019) 'Contribution of integrated forest-farm system on household food security in the mid-hills of Nepal: assessment with EnLiFT model', *Australian Forestry*, 82(sup1):32–44.

Chambers R (1979) *Rural development: putting the last first*, 1st edn, Routledge, London, UK.

Chambers R, Pacey A and Thrupp LA (eds) (1989) *Farmer first: farmer innovation and agricultural research*, Intermediate Technology Publications, London.

Chhetri RB (2009) 'From protection to poverty reduction: a review of forestry policies and practices in Nepal', *Journal of Forest and Livelihood*, 5(1):66–77.

Cronkleton P, Evans K, Addoah T, Smith Dumont E, Zida M and Djoudi H (2021) 'Using participatory approaches to enhance women's engagement in natural resource management in northern Ghana', *Sustainability*, 13(13):7072.

Crossland M, Chesterman S, Magaju C, Maithya S, Mbuvi C, Muendo S, Musyoki M, Muthuri C, Muthuri S, Mutua F, Njoki C, Sinclair F and Winowiecki L (2022) *Supporting farmer innovation to restore: an illustrated five step guide to applying the options by context approach to land restoration*, World Agroforestry, Nairobi, Kenya.

Erbaugh JT, Nurrochmat DR and Purnomo H (2017) 'Regulation, formalization, and smallholder timber production in northern Central Java, Indonesia', *Agroforestry Systems*, 91:867–880.

FAO (Food and Agriculture Organisation of the United Nations) (2022) *The state of the world's forests 2022: forest pathways for green recovery and building inclusive, resilient and sustainable economies,* FAO, Rome, Italy.

Fujiwara T, Awang SA, Widayanti WT, Septiana RM, Hyakumura K and Sato N (2018) 'Socioeconomic conditions affecting smallholder timber management in Gunungkidul District, Yogyakarta Special Region, Indonesia', *Small-scale Forestry*, 17:41–56.

Galabuzi C, Agaba H, Okia CA, Odoul J and Muthui C (2021) 'Women and youths' participation in agroforestry: what counts and what doesn't around Mount Elgon, Uganda?', *Journal of Mountain Science*, 18:3306–3320.

Gautam Y and Andersen P (2016) 'Rural livelihood diversification and well-being: insights from Humla, Nepal', *Journal of Rural Studies*, 44:239–249.

Gilmour DA and Fisher RJ (1991) *Villagers, forests and foresters: the philosophy, process and practice of community forestry in Nepal*, Sahayogi Press, Kathmandu, Nepal.

Gilmour D (2016) *Forty years of community-based forestry: a review of its extent and effectiveness*, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

He M, Huang S, Zhang Y and Rahman MM (2020) 'From peasant to farmer: transformation of forest management in China', *Small-scale Forestry*, 19:187–203.

Hobley M (1990) *Social reality, social forestry: the case of two Nepalese panchayats* [PhD thesis], Australian National University, Canberra, Australia.

Ifejika Speranza C, Wiseman U and Rist S (2014) 'An indicator framework for assessing livelihood resilience in the context of social-ecological dynamics', *Global Environmental Change*, 28:109–119.

Li TM (2007) 'Practices of assemblage and community forest management', *Economy and Society*, 36(2):263–293.

Lindayati R (2002) 'Ideas and institutions in social forestry policy', in Colfer C and Resosudarno IA (eds) *Which way forward: people forest, and policy making in Indonesia*, Resource for the Future, Washington; Center for International Forestry Research, Bogor; Institute of Southeast Asian Studies, Singapore.

Lowder SK, Skoet J and Raney T (2016) 'The number, size, and distribution of farms, smallholder farms, and family farms worldwide', *World Development*, 87:16–29.

Malla YB (2000) 'Impact of community forestry policy on rural livelihoods and food security in Nepal', *Unasylva*, 51(202):37–45.

Maryudi A, Nawir AA, Sekartaji DA, Sumardamto P, Purwanto RH, Sadono R, Suryanto P, Soraya E, Soeprijadi D, Affianto A, Rohman R and Riyanto S (2017) 'Smallholder farmers' knowledge of regulations governing the sale of timber and supply chains in Gunungkidul District, Indonesia', *Small-scale Forestry,* 16:119–131.

Meyfroidt P, Chowdhury RR, de Bremond A, Ellis EC, Erb KH, Filatova T, Garrett RD, Grove JM, Heinimann A, Kuemmerle T and Kull CA (2018) 'Middle-range theories of land system change', *Global Environmental Change*, 53:52–67.

Midgley SJ, Stevens PR and Arnold RJ (2017) 'Hidden assets: Asia's smallholder wood resources and their contribution to supply chains of commercial wood', *Australian Forestry*, 80(1):10–25.

Minang PA, Duguma LA and van Noordwijk M (eds) (2021) *Tree commodities and resilient green economies in Africa*, World Agroforestry, Nairobi, Kenya.

Nambiar EKS (2019) 'Tamm Review: Re-imagining forestry and wood business: pathways to rural development, poverty alleviation and climate change mitigation in the tropics', *Forest Ecology and Management*, 448:160–173.

Purnomo EP and Anand PB (2014) 'The conflict of forest tenure and the emergence of community based forest management in Indonesia', *Journal of Government and Politics*, 5(1).

Race D and Wettenhall G (eds) (2016) *Adding value to the farmers' trees: experiences of community-based commercial forestry in Indonesia,* Australian Centre for International Agricultural Research, Canberra, Australia.

Race D, Suka AP, Oktalina SN, Bisjoe ARH, Muin N and Arianti ND (2022) 'Modern smallholders: creating diversified livelihoods and landscapes in indonesia', *Small-Scale Forestry*, 21(2):203–227.

Reddy DN, Reddy AA, Nagaraj N and Bantilan C. (2014) *Rural non-farm employment and rural transformation in India*, Working Paper Series #57, International Crops Research Institute for the Semi-Arid Tropics, Research Program: Markets, Institutions and Policies: Telangana, India.

Ricciardi V, Ramankutty N, Mehrabi Z, Jarvis L and Chookolingo B (2018) 'How much of the world's food do smallholders produce?', *Global Food Security*, 17:64–72.

Riggs RA, Achdiawan R, Adiwinata A, Boedhihartono AK, Kastanya A, Langston JD, Priyadi H, Ruiz-Pérez M, Sayer J and Tjiu A (2021) 'Governing the landscape: potential and challenges of integrated approaches to landscape sustainability in Indonesia', *Landscape Ecology*, 36(8):2409–2426.

Roshetko JM, Pingault N, Quang Tan N, Meybeck A, Matta R and Gitz V (2022) *Asia-Pacific roadmap for innovative technologies in the forest sector*, Food and Agriculture Organization of the United Nations (FAO), Rome; Center for International Forestry Research, Bogor, Indonesia; CGIAR Research Program on Forests, Trees and Agroforestry.

Taylor M, McGregor A and Dawson B (eds) (2016) *Vulnerability of Pacific Island agriculture and forestry to climate change*, The Pacific Community, Noumea, New Caledonia.

Safitr MA (2010) 'Community-based forest management in Indonesia: solving two centuries of social and environmental injustice?' in Safitri MA [PhD thesis] *Forest tenure in Indonesia: the socio-legal challenges of securing communities' rights*, Leiden University, The Netherlands.

Thornton PK, Kristjanson P, Förch W, Barahona C, Cramer L and Pradhan S (2018) 'Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge?', *Global Environmental Change*, 52:37–48.

Urano M (2013) *Problems in Indonesian community-based forest management policies: examination of village forest (HD) programs in the provinces of Jambi and East Kalimantan*, Hokusei Gakuen University, Hokkaido, Japan.

Vadjunec JM, Radel C and Turner BL (2016) 'Introduction: The continued importance of smallholders today', *Land*, 34(5):1–12.

Wilson GA (2007) *Multifunctional agriculture: a transition theory perspective*, CAB International, Wallingford, United Kingdom.

Chapter 2

Domesticating wild tree crops in the South Pacific

Tony Page, Paul Macdonell, Lex Thomson
and John Doran

Abstract

Small island states in the South Pacific region face significant development challenges that have culminated in a low level of investment in the diversification of agricultural exports. There are, however, opportunities for a range of native tree species and perennial crops to be integrated as agroforestry, and yield products for the domestic and export markets. Forest tree cropping – planting a forest for the purposes of selling forest products – could generate much greater local and national economic benefits than continuing to harvest trees from already depleted native forests. The benefits of a planted forest can accrue over time and contribute to medium-term and long-term wealth creation, while also having environmental and food security advantages. A plantation-based approach to restoring natural stands can be readily incorporated into existing agroforestry systems without substantial modification. Ownership and sale of products from planted trees are generally less complicated than extraction of natural resources from communally owned customary land. Plantations can be located closer to infrastructure and markets than natural forests. Product quality can be optimised through tree management, including silvicultural interventions, to promote higher returns. A higher density of trees compared to the natural forest can require less management, with simple onsite processing and/or value adding increasing the value of the plantation. In addition, a grower using genetically improved germplasm can expect fewer inputs, higher productivity and shorter rotation length compared to wild unselected stock.

In this chapter, we consider domestication in a broad sense as encompassing the whole value chain, from selection of candidate tree species, germplasm collection and breeding, plantation silviculture, to processing and marketing. In some land-use systems and regions of nations in the south-western Pacific, the production of high-value trees could be developed on a commercial scale (Carias et al. 2023). We explore progress in the domestication of sandalwood, whitewood and *Canarium* in Melanesia, which has started to make high-quality germplasm available to prospective growers, while facilitating highly productive plantings and developing their utilisation and marketing.

Acknowledgement

We pay tribute to our fellow author, Dr Tony Page, a senior research fellow with the University of the Sunshine Coast's Tropical Forests and People Research Centre, who tragically died in Timor-Leste in June 2024. Tony dedicated his career to helping rural communities in Papua New Guinea, Vanuatu, Timor-Leste, Indonesia, and north Queensland make better use of local tree resources to generate income and improve their livelihoods. He is internationally recognised for this work, which included genetic improvement, silviculture and forestry extension for sandalwood, teak, and other high-value tropical tree crops. His research directly resulted in the development and better use of genetic resources, ex-situ conservation of threatened key tree species and provenances, and increased investment in smallholder commercial tree planting. It spawned innovative approaches to forestry and agroforestry in the South Pacific islands, helping to address socioeconomic and environmental issues associated with logging and deforestation, and improving smallholders' lives and livelihoods. Tony's genuine desire to help smallholders improve their livelihoods and his enthusiastic, friendly nature meant that he was much loved wherever he went. Immersing himself in village life, he was easily accepted and, in many villages, adopted as "one of their own". He freely shared his knowledge, gave generously of his time to colleagues, and mentored many early-career researchers. This chapter is just one part of Tony's substantial legacy to improving agroforestry and forest management by smallholders. We miss you, fellow, and will make sure your legacy lives on.

We also thank Dr David Bush who reviewed drafts of this chapter and provided helpful insights.

Background context

Small island states in the South Pacific region are some of the world's least developed nations, with economies reliant upon tourism, remittances, external aid and agriculture (Connell 2007, 2010; Naidu 2010; Bolesta 2020). With little diversification of the agricultural export economy during the post-colonial period, sectors such as tourism and remittances are seen as attractive (Brown et al. 2014; Cheer et al. 2018). An over-reliance on international tourism has left several Pacific island nations exposed to the contraction of the tourism sector associated with the COVID-19 pandemic. The flow of remittances over the same period has been more resilient, despite restrictions on international travel (Howes and Surandiran 2020; Kumar and Patel 2021). As Pacific island nations seek a path out of the pandemic, it is timely to consider the strategic diversification of their export economies. Morgan (2013) suggested that agriculture in the Pacific region is the greatest source of livelihoods, cash employment and food security.

Pacific island nations encounter a range of economic challenges related to their distance to market, diseconomies of scale, small domestic markets, limited natural resource and production base, vulnerability to external shocks and natural disasters, and paucity of investment (Connell 2007; Jones 2012; Fargher et al. 2018; Bolesta 2020; Carias et al. 2023). Economic diversification could provide an alternative income source to commodity crops, which are characterised by large and unpredictable fluctuations in their international market, rendering them less reliable sources of smallholder income and foreign exchange (Connell 2007). In the Pacific region, agricultural diversification can incorporate natural resources where local producers are competitive in a global marketplace, including niche value-added products, which have a market edge through biological, geographical, organic and/or social advantage (Connell 2007; Carter and Smith 2016; Nurse 2016; Carias et al. 2023). While there have been some successes with niche products – such as Fiji Water, kava, turmeric and ginger – the potential for other niche products is yet to be fully explored in the context of Melanesia (Jones 2012; Carter and Smith 2016).

Forests and trees are particularly important in the economic, social, environmental and cultural lives of Pacific islanders (Thomson et al. 2018a). Historically, forests have produced timber resources that have been a valuable source of foreign exchange (Bond 2006). Unfortunately, many natural forests have been degraded, reducing species and product diversity, destroying habitat and introducing invasive exotic species (Thomson et al. 2018a). With strong demand for forest products set to continue, supply is shifting from natural to planted resources within the region (FAO 2019). In Papua New Guinea (PNG), Bourke (2009a:346) suggests that the forest industry will likely transition from exploitation of native forests to a greater reliance on planted woodlots managed by customary landholders. Perennial agroforestry gardens are key livelihood assets and increased planting of indigenous tree species for resource production could bring gender-inclusive cash and livelihood benefits for landholders (Addinsall et al. 2016). Wilkie et al. (2002) suggest that the prospects for forestry in the Pacific region depend upon governments taking the lead in adopting sustainable management of natural forests and developing plantation sectors that include processing infrastructure.

Tree cultivation, agroforestry and improved fallows with indigenous tree species during the cropping rotation can contribute positively to agricultural and forest biodiversity, food and livelihood security, rural household income diversification, provision of environmental services, and improved resilience to climate change (Leakey and Tchoundjeu 2001; Schreckenberg et al. 2006; Thomson et al. 2018a; Chazdon and Brancalion 2019; Leakey 2019). Growing local tree species that would previously have been targeted for harvest offers scope for re-establishing these species to restore their resources and recover biodiversity (Martin et al. 2021). However, if tree crops are planted to increase cash income, the species should be selected with a clear market focus (Underhill et al. 2011), preferably with local use as well as domestic and export market potential.

Tree domestication

Plant domestication is one of the oldest of human innovations to bring about improvements in agricultural productivity (Sauer 1952; Harlan 1971). It is a process of human-imposed selection that alters both the phenotype and the genotype of a crop plant compared with its wild relatives (Zohary 2004; Olsen and Wendel 2013). The altered phenotype of a domesticated plant is more desirable for people and thereby increases the benefits associated with its cultivation (Zohary 2004). Tree-crop domestication is no exception, with many fruit trees the focus of selection and propagation dating back thousands of years (Galindo-Tovar et al. 2008; Stettler 2009; Weiss 2015; Shen and Li 2021). Natural forests, however, remain the primary source of timber and non-wood forest products (Fenning and Gershenzon 2002).

While an abundance of forests in the tropics has provided people with valuable products over generations, historically there has been little incentive to cultivate and domesticate such forest trees (Evans 2009:9). As the global population has grown, the demand for timber and agricultural land have contributed significantly to the conversion and degradation of forests, particularly in the tropics (Gibbs et al. 2010; Shearman et al. 2012; Warman 2014; Henders et al. 2015). With timber resources from natural forests declining or becoming protected, there has been increasing emphasis on expanding timber plantations to meet the shortfall (Paquette and Messier 2010; Silva et al. 2019). The greatest expansion of the global forest plantation estate has come from industrial sources, typically planting for commercial export markets (Schirmer et al. 2015). As land becomes increasingly scarce in many areas, future expansion is likely to depend upon forests planted by smallholders (Harrison and Herbohn 2000; Midgley et al. 2017).

It is within this developmental context that the domestication of forest trees has become important, and it is only in comparatively recent times that tropical forest trees, other than fruit trees, have undergone the initial stages of domestication (Zobel and Talbert 1984; Turnbull 2002; Burley and Kanowski 2005; Sederoff et al. 2009). There are exceptions – pollen evidence shows that *Casuarina* in New Guinea (Haberle 2007) was cultivated about 1,000 years ago; outside the Pacific region, teak (*Tectona grandis*) was planted in the 15th century in Java (Evans 2009); and *Populus* was domesticated at the end of the 17th century (FAO 1979). However, the systematic domestication of timber tree species has primarily been occurring only since the 1950s (White et al. 2007), with a focus on key genera such as *Acacia, Casuarina*, *Eucalyptus*, *Pinus,* and *Tectona* (Campbell et al. 2003; Midgley and Turnbull 2003; Simons and Leakey 2004; Del Lungo et al. 2006; Graudal and Møestrup 2017; Pinyopusarerk 2020). More recently, the domestication of Pacific tree species for smallholder production in woodlot and agroforestry systems is being considered as an effective means for addressing a shortage of locally available products, replacing imports or supplying export markets (Leakey and Simons 1998; Nichols and Vanclay 2012; Leakey 2019).

Benefits of tree domestication

As discussed, domestication brings about changes in the phenotype and genotype of the tree crop through selection and breeding. Tree improvement helps to make the best use of the land committed to tree production, regardless of the product, because the land is typically the most valuable part of a tree planting investment, owing to the opportunity costs associated with its use for other productive purposes (Eldridge et al. 1993a). The traits under selection (for example, yield, disease resistance or product quality) should be those that producers and consumers value. The benefits of domestication will depend on the scale of improvement in the desirable trait(s) relative to undomesticated, or to the previous generation of trees. The adaptability of a domesticated form to cultivation, including the level of inputs and outputs from that cultivation, will influence its intrinsic value for producers. The benefits will also be modified by the value that the market places on the improvement(s) made to the selected trait(s) (Leakey and Simons 1998).

The process of domestication is substantially influenced by the biology of the species concerned and is, therefore, highly variable (Thomson et al. 2002). In addition to biology, the level of investment in domestication dictates the approaches that can be taken. At one end of the scale, domestication may involve identifying good seed sources and developing suitable practices for their propagation and silviculture. Alternatively, domestication may involve a range of genetic and other biotechnologies to improve the selection process and shorten generation times (Harfouche et al. 2012). Simons and Leakey (2004) suggest that domesticating agroforestry trees can take a farmer-driven participatory approach where the intraspecific diversity of locally important species forms the basis for selecting phenotypes that meet the needs of subsistence farmers, as well as domestic markets. A participatory approach to domestication, which involves farmers in the improvement process, can empower local innovation and ownership (Ceccarelli and Grando 2007; Leakey et al. 2012).

Tree improvement strategies are influenced by the level of genetic variation present in the trait(s) of interest and involve optimising genetic gain in the short term, while also establishing a basis for long-term genetic improvement (Burley and Kanowski 2005). The purpose of selection is to increase the frequency of alleles that influence the expression of the desirable traits. The efficiency of selection is influenced by the traits being selected (for example, yield or disease resistance), with greater gains being achieved under intensive selection (where only the very best phenotypes are selected for the next generation); and where the traits are under strong genetic control (White 1987) with an absence of adverse genetic interactions. A species' particular reproductive biology and capacity for clonal propagation, together with its period of juvenility, should have a major influence on the choice of the domestication strategy (Potts 2004).

Broader concept of domestication

Nichols and Vanclay (2012) stressed the importance of considering domestication in the context of the entire value chain, from candidate species selection through to silvicultural management and, finally, processing and marketing. Domestication encompasses not just tree breeding, but any activity that improves the utilisation of the species. Domestication includes commercialisation because, without a ready market for the products of domestication, the incentives to domesticate intensively for self-use are insufficient (Leakey and Simons 1998). Roshetko and Verbist (2000) describe domestication as a cycle of activities whereby the progression from wild to transformed state do not need to be conducted in sequence, but rather any of the 8 activities can be undertaken separately or in combination with the others (Figure 2-1).

For instance, with *Canarium* spp. a resource base already existed, and so it was prudent to focus on the utilisation and marketing of the product to meet the immediate demand. The exploration and collection phase to evaluate species diversity and select trees for inclusion into the breeding population is a long-term activity and would not assist with the immediate needs of the species utilisation.

On the other hand, whitewood (*Endospermum medullosum*) has been harvested from native populations for timber production and there is evidence that over-harvesting has caused the loss of entire tree populations (Doran et al. 2012). In this case, the most important activity is exploration and collection so that the genotypes can be secured in breeding trials that also act as ex situ conservation stands, or gene banks.

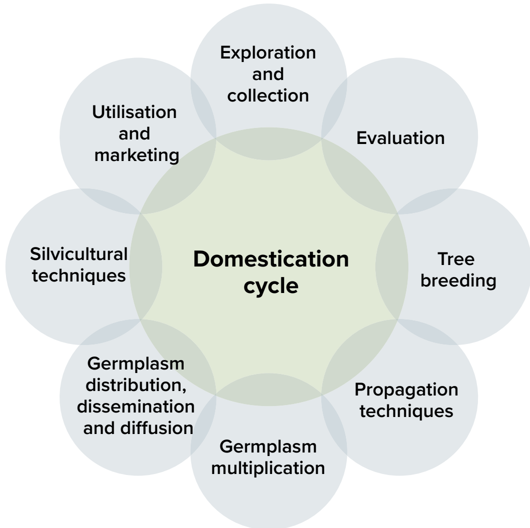

Figure 2-1: Domestication cycle adapted from Roshetko and Verbist (2000). Domestication can follow logical progression starting at 'Exploration and collection' and following in a clockwise direction. It can also start at any point in the cycle and activities can occur simultaneously depending upon the strategy adopted.

While market potential for native trees is important, so too is the development of supportive value chains to ensure the tree crop and timber products can reach their intended market at a competitive price and high quality (Anyonge and Roshetko 2003; Jansen et al. 2020). According to Carias et al. (2022), strategies to incorporate smallholder tree growers into value chains should be based on knowledge of demand, infrastructure, policy, smallholder assets and interests, and biophysical suitability. Focusing on specific regions within countries is important to ensure that conditions are suitable for growing, harvesting, transporting, processing and marketing the proposed tree products (Carias et al. 2022).

Tree domestication in the Pacific

The agricultural practices of societies across the Pacific are characterised by a complex arboriculture where trees of utility are foraged, protected and nurtured, or actively cultivated (Yen 1993, 1996; Walter and Lebot 2007). This form of arboriculture is widespread throughout the Pacific islands and can be traced back thousands of years to the late Pleistocene (Kirch 1989; Kennedy 2012), with domestication of *Canarium* spp. possibly undergoing initial genetic selection for fruit production traits during the early and mid-Holocene (Ellen 2019). There is evidence that *Canarium* has strong cultural and spiritual significance among producers in Solomon Islands (McClatchey et al. 2006). Of the 40 tree species in Vanuatu with edible fruits, about 30 are not cultivated, but they are an important source of opportunistic food (when walking or hunting in the forest) or famine food (after a cyclone). Some species that are harvested and eaten in abundance are not explicitly planted, but are protected and nurtured, including sea almond / natapoa (*Terminalia catappa*), burckella/bukbuku (*Burckella obovata*) and dragon plum (*Dracontomelon vitiense*).

The most coveted fruit and nut trees are actively cultivated and include breadfruit (*Artocarpus altilis*), cutnut (*Barringtonia* spp.), *Canarium* nut (*Canarium* spp.), golden apple or wi-apple (*Spondias cytherea*), Tahitian chestnut (*Inocarpus fagifer*), oceanic lychee (*Pometia pinnata*) and Malay apple / kavika (*Syzygium malaccense)* (Walter and Sam 2002). These actively cultivated species have given rise to domesticated forms through the repeated selection of particular individual plants and their propagation over many generations. Selection can be based on preference, necessity or prudence – preference if the tree has desirable characters (sweeter and less fibrous produce); necessity if it has features not evident in other trees (storing or preserving ability); and prudence if it has some durability feature (early or late fruiting, resistant to problems) (Walter and Sam 2002).

In the south-western Pacific region, there is much potential for incorporating commercial tree production into traditional agroforestry systems. Customary landowners have a history of integrating a range of tree products into agriculture. Those with examples are timber (*Casuarina* spp., balsa), food (breadfruit, *Canarium* spp.), medicine (noni), extractives (sandalwood) and intoxicants (betel nut, kava) (Clark 1993; Yen 1996; Bourke 2009b, 2018; Rome et al. 2020). More recent exotic cash crop examples include coffee, cocoa and oil palm (Kanowski et al. 2014; Bourke 2018). The collective experience gained from incorporating these tree crops, as well as their commercialisation, is relevant in informing further diversification into other commercial tree-crop species. Furthermore, the domestication of indigenous tree crops such as *Canarium* (Matthews and Gosden 1997; Thomson and Evans 2006a) provides a model for considering the participatory domestication of new crops. While the domestication of new indigenous tree species might be constrained by information about their genetic diversity, this can be potentially offset by customary knowledge about phenotypic diversity and the presence of traits important for local livelihoods (Leakey 2019).

Across many tropical countries, participatory domestication is being used to address localised timber shortages, diversify income and reduce dependence on natural forests (Leakey 2019). Unlike the approach for large commercial plantations, with participatory domestication, extension services, education and information dissemination are important for ensuring quality control of the end product and profitability of production.

The participatory approach was pioneered in Africa through the work of the World Agroforestry Centre (ICRAF) and in 2006 about 5,000 farmers were practising participatory tree-domestication techniques with *Dacryodes edulis* and *Irvingia gabonensis* (Tchoundjeu et al. 2006). Rural communities selected trees that met their requirements and scientists assisted with the technical aspects to facilitate clonal propagation of these selections. The program was farmer driven and no subsidies were provided to encourage participation. Participatory domestication is a model that assists producers in areas where there is little external funding for development. With teak in Indonesia, for example, smallholders were unaware of good tree management and harvested logs were affected by decay from improper pruning, knots from large branches, and short piece lengths. This resulted in 40% of timber sent to buyers being rejected (Race and Wettenhall 2016).

In the Pacific region, SPRIG, the South Pacific Regional Initiative on Forest Genetic Resources (Boland and Thomson 1999), has worked with forestry departments and local communities in Solomon Islands and Vanuatu to bring together Pacific island selections of fruit and nut trees, such as *Canarium indicum* and *Terminalia catappa*, made over thousands of years (Lepofsky 1992; Walter and Sam 1993; Yen 1996; Walter and Sam 2002), into formal trials in an effort to produce further gains through seed distribution[2]. These collections are built on earlier varietal collections in both countries and in PNG.[3]

2 See, for example, Evans (1999b), Ngoro et al. (2006), Sam et al. (2002), Smith et al. (2005) and Viji et al. (2000).

3 See, for example, Evans (1991, 1999a) and Walter and Sam (1993).

Another Pacific example involves the expansion of sandalwood (*Santalum austrocaledonicum*) planting in Vanuatu where the planting rate increased almost 30-fold in the 7 years from 2000 to 2006 compared to the previous 7 years (Page et al. 2010a). The increase was likely influenced by a combination of factors including a declining natural resource, government policy, donor-funded projects, extension services, distribution of nursery planting bags, and the increase in farm-gate prices above the Vanuatu consumer price index (Page et al. 2010a). These factors presented an attractive opportunity, and farmers responded by establishing a resource base, which recently provided 5.5 times the average annual harvest of 31 tonnes between 2011 and 2018 (Page et al. 2020a; DoF unpublished data 2022).

Species selection

While tree domestication can be used to improve the quality and yield of more naturally managed forests, maximum benefits are derived from domestication when trees are grown under intensively managed plantings (White et al. 2007). Access to forest products, including timber, has become limited in some areas through the combined effects of forests being converted to agriculture and logging or mining in adjacent accessible forest. While landholders remain interested in planting trees, even in forested areas (Page et al. 2016), the types of products, the length of their rotation and the inputs required influences their decision-making about their suitability to tree planting (Walters and Lyons 2016). Species selection is, therefore, a critical aspect of domestication to ensure that the end products address landholder needs and interests.

In the Pacific region, many tree species are candidates for domestication (Table 2-1). Below, we explore the approaches used and the benefits derived from the domestication of 3 indigenous tree crops:

- sandalwood (Bush et al. 2020c; Page et al. 2020a)
- whitewood (Page et al. 2017)
- *Canarium* (Randall et al. 2016).

Table 2-1: Candidate species for domestication and production in smallholder woodlots and agroforestry systems

Category	Species	Traditional/ Recent	Reference
Fruit	*Artocarpus altilis*	Traditional	Thomson et al. 2024; Elevitch and Ragone 2018
	Dracontomelon vitiensis	Traditional	Walter and Sam 2002
	Pandanus tectorius	Traditional	Thomson et al. 2018g
	Pometia pinnata	Traditional	Walter and Sam 2002; Thomson and Thaman 2018
	Spondias dulcis	Traditional	Morton 1987; Verheij 1991
	Syzygium malaccense	Traditional	Hong et al. 2018
	Terminalia solomonensis	Traditional	Henderson and Hancock 1988
Nut	*Barringtonia edulis*	Traditional	Thomson and Sam 2018
	Barringtonia novae-hiberniae	Traditional	Walter and Sam 2002
	Barringtonia procera	Traditional	Pauku 2006; Thomson and Sam 2018; Pauku et al. 2010
	Calophyllum inophyllum	Recent	Thomson et al. 2018b

Category	Species	Traditional/ Recent	Reference
Nut	*Canarium harveyi*	Traditional	Thomson and Evans 2006b
	Canarium indicum	Traditional	Randall et al. 2018; Bunt and Leakey 2008; Nevenimo et al. 2007
	Cocos nucifera	Traditional/ Recent	Bourdeix and Batugal 2018
	Inocarpus fagifer	Traditional	Thomson 2018a; Pauku 2005; Pauku et al. 2010
	Terminalia catappa	Traditional	Thomson and Evans 2018; Morton 1985
	Terminalia kaernbachii	Traditional	Jarua and Uwamariya 2004; Johns 1991
Timber	*Acacia auriculiformis*	Recent	Pinyopusarek et al. 2018
	Acacia crassicarpa	Recent	Midgley and Thomson 2018
	Acacia mangium	Recent	Arnold 2018
	Agathis macrophylla	Recent	Keppel et al. 2018
	Alphitonia zizyphoides	Recent	Thomson and Thaman 2006
	Araucaria cunninghamii	Recent	Nikles and Arnold 2018
	Casuarina equisetifolia	Recent	Pinyopusarerk and Midgley 2018; Bush et al. 2020b; Nicodemus et al. 2020
	Casuarina oligodon	Traditional	Ataia 1983; Agiwa and Uwamariya 2004; Thomson and Gâteblé 2020
	Dracontomelon dao	Recent	Uwamariya 2004
	Endospermum medullosum	Recent	Thomson et al. 2018a; Vutilolo et al. 2005; Doran et al. 2012, 2021b
	Eucalyptus camaldulensis and *E. tereticornis*	Recent	Arnold and Luo 2018
	Eucalyptus degupta	Recent	Eldridge et al. 1993b; Davidson et al. 2004
	Eucalyptus pellita	Recent	Harwood 2018
	Falcataria moluccana	Recent	Macdonell and Baskorowati 2018
	Flueggea flexuosa	Traditional	Thomson 2006b; Pouli et al. 2018
	Intsia bijuga	Traditional	Thomson et al. 2018h
	Pinus caribaea var. *hondurensis*	Recent	Dvorak et al. 2000
	Pterocarpus indicus	Recent	Thomson 2018b
	Swietenia macropylla	Recent	Mayhew and Newton 1998; Thomson et al. 2018d
	Tectona grandis	Recent	Pedersen and Gua 2018
	Terminalia richii	Recent	Thomson et al. 2018e
Extractives	*Gyrinops ledermannii*	Traditional	Lata et al. 2018
	Santalum album	Recent	Thomson et al. 2018f
	Santalum austrocaledonicum	Traditional	Page et al. 2018; Thomson 2006c; Page et al. 2020a
	Santalum yasi	Traditional	Thomson et al. 2018c; Bush et al. 2021; Bush et al. 2020c; Thomson 2006c

Sandalwood – *Santalum* spp. (*S. austrocaledonicum, S. macgregorii, S. yasi*)

Sandalwood is a small tree that produces a fragrant heartwood that is used in aromatic products such as incense, perfumes and therapeutic preparations. Much progress has been made with the domestication and smallholder adoption of sandalwood and it is now widely planted in many areas across the Pacific. In Vanuatu, the domestication of its native sandalwood (*S. austrocaledonicum*) was based on an assessment of variation in alpha-santalol and beta-santalol in the heartwood of individual trees across its known distribution. Similar studies of intraspecific variation in heartwood characteristics have also been conducted with sandalwood in Fiji and Tonga (*S. yasi*) (Bush et al. 2020a), PNG (*S. macgregorii*) (Page et al. 2020b), northern Queensland, Australia (*S. lanceolatum*) (Page et al. 2007) and Timor-Leste (Almeida et al. 2022). In Vanuatu and Queensland, individual trees containing heartwood with elevated levels of santalol were selected from each population and initially captured in one grafted clone archive / seed orchard in each country (Page et al. 2010b; Lee et al. 2019). In Vanuatu, they were then replicated across 7 islands noted for their suitability for cultivating the species, using most of these clones at each site to ensure that improved seed was available locally. A gene conservation stand was also established and includes most island provenances (Page et al. 2020a). In Queensland, a conservation enrichment planting and progeny trials were established to provide an ongoing source of material for further assessment and selection (Lee et al. 2019).

Systematic participatory domestication strategies have now been developed for advancing the production of sandalwood in Vanuatu (Page et al. 2020a; Doran et al. 2021a). The strategy is to establish all available selected clones in grafted seed orchards with reliable growers on the main sandalwood islands to conserve the selected genotypes, as well as ensure that high-quality seed is readily available. New selections from established plantations will be added over time to each orchard in a 'rolling-front' breeding strategy to increase the genetic base. Progeny trials will progressively provide information on the performance of each family to allow backward and forward selection among the clones in each of the orchards. While the selection criterion has been based on high levels of santalol, it is growth rate, rate of heartwood formation, tree form and disease resistance that will ultimately determine which clones remain in the seed orchards. The selected growers are responsible for the fair and equitable distribution of orchard seed among eligible growers on their respective island.

Fijian/Tongan sandalwood (*S. yasi*) has been characterised by apparently high levels of inbreeding, gauged by DNA markers, among its scarce and highly fragmented wild populations (Bush et al. 2016). Fiji has introduced *S. album*, which has been widely planted within agricultural areas. Now that *S. album* is widespread, its presence is considered a potential threat to the pure *S. yasi* gene pool through hybridisation and introgression. While the domestication strategy for Fijian sandalwood follows a similar approach to Vanuatu, in Fiji more emphasis has been placed on securing and conserving existing genetic variation within the species (Bush et al. 2020c). This includes provision for establishing ex situ and circa situm conservation stands that together adequately represent the remaining diversity of *S. yasi*. Further to this, establishing replicated provenance-progeny trials, which contain selections from across the species' natural range, is designed to promote outcrossing and provide a resource to make growth-based and heartwood-based selections for further breeding (Bush et al. 2020c). The focus of germplasm deployment includes producing genetically diverse seed crops so that smallholders can establish highly productive and valuable plantings.

In the meantime, sandalwood trade continues and a grower guide was published to empower growers in Vanuatu to make more informed decisions about their tree management. The guide aims to help growers optimise returns by making specified silvicultural interventions when required (Page et al. 2012b). Now extended, this guide applies to all sandalwood species of interest in the south-western Pacific (Page et al. 2022a). A standardised sandalwood grading system has also been produced to educate growers about the different grades of sandalwood and their commercial value (Page and Doran 2021). The transition from a wild to planted resource means that higher inputs are needed and growers have to take steps to optimise their financial returns. Making this information widely available helps smallholders optimise their returns by producing products to required specifications.

Box 2-1: **Grower profile for sandalwood production in Vanuatu**

In Vanuatu, sandalwood planting has been prominent in the southern islands for 20 years. These islands offer insight into the potential impact for sandalwood production in other areas, where growers begin to harvest their trees to benefit their livelihood.

It is said in the islands that all people plant sandalwood, regardless of age, gender or profession. One example is Naomi, from Loqueria village on Tanna Island, whose main sources of income are a market garden and sandalwood. A mother of 7 children, Naomi has been planting sandalwood since her marriage. Her husband, Yoyap, works in hospitality associated with the tourism industry and in the early years of their marriage he worked away from home. It was around this time that Naomi thought about the future of their children. With limited education herself, she decided to plant sandalwood to pay for their school fees so that they had better opportunities in life. This goal was achieved with her first-born child (now 28 years old) and continues with her other children (the youngest being 5 years old). Surplus funds are used to purchase basic household items such as cooking oil, rice, soap and salt. The original mother trees used to supply the seed belong to a cousin located in a distant village. Naomi's largest planting is about 300 stems planted 3 to 4 years ago.

Sandalwood seedlings are typically planted within a yam garden once the yams are harvested. When Severe Tropical Cyclone Pam crossed Tanna Island in 2015, Naomi was very concerned for her sandalwood. While many trees were damaged, she was able to recover most of them. This included propping up, pruning and increased weeding as the vines were some of the first things to recover. Some trees that were knocked down during the cyclone were able to be salvaged and one of these trees fetched US$300 for the family. Despite the impact of the cyclone, Naomi's interest in planting sandalwood has not waned. She views the species as being accessible to plant by women, being adapted to her local environment and providing good long-term income.

Box 2-2: **Grower profile for sandalwood production in Papua New Guinea**

On the south coast of Papua New Guinea, sandalwood has been produced intermittently through the nurturing or transplanting of wild seedlings. It is only in recent years that families have engaged in producing seedlings and establishing agroforestry sandalwood systems. Leveraging existing knowledge on sandalwood production, they have established modest but productive systems by incorporating annual and perennial agricultural crops with locally adapted host trees.

In Rigo District, the families of Sebara Baina and his brother have implemented a model sandalwood agroforestry system to produce short-term returns (corn, cucumber, yam, aibika, watermelon, sweetpotato and peanut are initially planted, followed by banana, pineapple, pawpaw and cassava), medium-term returns (vanilla, sandalwood seed), and long-term returns (oil-rich fragrant heartwood for export). A 1-ha site dominated by *Imperata cylindrica* (cogon or bladey grass) was reclaimed through mechanical ploughing, and planted with rows of vegetables, fruits and root crops for the first 12 months. Sandalwood and host seedlings were planted over 7 months with a total of 221 sandalwood trees and 204 host trees (*Cassia fistula* and *Leucaena leucocephala*) planted in single-species rows. Initial financial returns were made by marketing the significant food crops on site, with some of the vegetables harvested for self-consumption and the surplus sold at market. Annual returns over the first 4 years approached US$800 mainly through the sale of corn, cucumber, watermelon and pineapple.

The 2 families have supplied more than 1,000 sandalwood seeds to their nearby communities who have germinated them, and this activity continues. This informal, extension-based training has increased local interest in planting sandalwood, resulting in increased demand for sandalwood seed and seedlings.

Whitewood (*Endospermum medullosum*)

Whitewood (*Endospermum medullosum*) is Vanuatu's local species alternative to imported *Pinus radiata* timber. It is suitable for framing, furniture making, light construction and interior joinery (Thomson 2006a). Although non-durable (Aru et al. 2012), it is readily treatable with preservatives to prevent blue stain and pinhole borers (ambrosia beetle) (Viranamangga et al. 2012). In the 1990s, whitewood was the most significant native timber tree harvested from wild stands across northern Vanuatu and accounted for between 40% and 60% of all timber extracted from wild sources. Its over-harvesting was acknowledged by the Vanuatu Department of Forests (DoF), who, in partnership with the regional SPRIG program, developed a 10-step conservation strategy (Corrigan et al. 2000). Still, logging of whitewood continued unabated until it was commercially exhausted and exports effectively ceased after 2008 (Viranamangga et al. 2012).

The restoration of a whitewood industry is reliant upon the development of a planted resource. This work began in the late 1990s when SPRIG established a progeny trial of 15 provenances sourced from 6 of Vanuatu's islands (Vutilolo et al. 2005). It was continued through an ACIAR project (FST/2008/010), which characterised genetic variation in key traits from the trial and made selections to establish 2 second-generation progeny trials (Doran et al. 2012), now over 10 years old. At that time, 9 of the 15 provenances from the original SPRIG trial were considered extinct in the wild (Doran et al. 2012). This highlights the dual importance of tree improvement programs not only for domesticating a species but for conserving genetic resources. Together, these domesticated species and genetic resources are now supporting smallholder-farmer forestry and community-based forestry by ensuring that plots established are using the best available genetically improved seed.

The domestication strategy for Vanuatu whitewood was updated recently (Doran et al. 2021b). Smallholder farmers were identified as the main beneficiaries because the species is highly suitable for cultivation in small woodlots and agroforestry systems. The area established with whitewood agroforestry is modest but expanding (Glencross and Viranamangga 2012; Page et al. 2012a). For the first 2 to 5 years, growers typically intercrop with staple crops and other vegetable/fruit crops, and plant big-leaf mahogany (*Swietenia macrophylla*) and sandalwood (Aru et al. 2012). Many farmers surveyed in 2008 said they intended to increase their area planted to whitewood (Aru et al. 2012). By increasing the availability of improved whitewood germplasm, these and other growers can benefit from the gains made in breeding to improve the quality of whitewood traded. While domestic demand for defect-free whitewood exceeds supply, the market for lower-grade whitewood that is sourced from smallholder woodlots needs to be further developed (Viranamangga 2013). This can be achieved through improving processing of smaller-diameter logs, sharing profits along the supply chain more equitably, and promoting consumer acceptance for whitewood timber with a higher incidence of wood knots and a slightly deeper colour (that is, not perfectly white) (Carias et al. 2022).

Canarium indicum

For thousands of years *Canarium indicum* has been an important plant for communities in Vanuatu, Solomon Islands and PNG, where it is referred to as *Canarium*, nangai, galip or ngali. Grown primarily for its nut, *Canarium* is also used for its timber and for cultural purposes (Thomson and Evans 2006b; Randall et al. 2018). Tree selection has occurred informally over many generations by transplanting seedlings from beneath desirable trees to accessible locations (village areas, family gardens), as well as moving seedlings between islands. While some specific selection against sparse fruiting and small nut size trees has been made by felling less desirable trees for timber use, these traits are still widespread and a large variation in fruiting characteristics is observed within populations (Grant et al. 2023).

Box 2-3: **Grower profile for whitewood production in Vanuatu**

The island of Espiritu Santo in northern Vanuatu offers ideal conditions for producing whitewood – high and uniform annual rainfall, a consistently warm tropical climate, and deep, fertile soils. In the village of Lolat-Sara on the east coast of the island, Malakai Moses Vele is a progressive farmer who began planting his 10 ha of whitewood for sawn timber over 20 years ago. He was among the first in the area to adopt this previously wild-harvest crop and was the first to begin using the thinnings for timber production and selling them commercially. Many whitewood woodlots begin their life as agroforestry plantings where they are planted in combination with other tree species (mahogany, natapoa and *Flueggea*), as well as agricultural cash crops (kava), food crops (taro, banana, yam and papaya) and silvopastoral systems (coconut and cattle). Such systems benefit from lower labour inputs relative to monocultures and early cash income from harvesting agricultural crops and mid-rotation harvesting of companion trees (*Flueggea*) used in local construction and sale.

The desire to consume *Canarium* nuts is still strong in today's society and demand for processed nuts frequently exceeds supply (Wallace et al. 2016). Documented domestication progress in all 3 countries has waxed and waned over the past 20 years due to variable external funding. However, PNG has made the greatest inroads by introducing mechanical processing of whole fruits to the kernel-in-testa stage (Wallace et al. 2021). Superior kernel trees were selected from natural populations in PNG to establish seed orchards and produce improved seed in 1998 and 2002 (Leakey et al. 2008), and in 2007 (Cornelius et al. 2012); in Solomon Islands between 1988 and 1991 (Evans 1999); and in Vanuatu from 1991 to 1993 (Walter and Sam 1993) and from 2017 to 2018 (Macdonell 2018). The knowledge gained across various *Canarium* projects on its growing and processing has recently been synthesised into a production manual (Grant et al. 2022) to make this information more widely available.

Box 2-4: **Community processing of *Canarium* from a scattered resource**

The cultural significance of *Canarium* across PNG, Solomon Islands and Vanuatu, and its long association with these countries, has resulted in many families owning a small number of trees as part of their subsistence livelihoods. This number of trees is enough to provide kernels for the family to eat or for selling on sticks at local markets. But it is generally not enough for a family to regularly supply kernels to processors. Cracking is a time-consuming process that requires many hands to make sure the kernels are shipped before they spoil.

To circumvent this, in Vanuatu, island communities pool their resources and come together as a social activity to supply kernels in testa to commercial suppliers in Port Vila. Bill Maki, a broker on Paama island, tells the story of how one Sunday afternoon after church, a group of 5 or 6 people gathered fruits from easily accessible trees and transported them by vehicle back to the village of Tavie. On Thursday afternoon and Friday morning, 18 women (plus children) gathered to crack the fruits and extract the kernel before the flight to Port Vila mid-Friday morning to freight the kernels. This shipment was 44 kg of kernels in testa, which equates to a modest income of US$120 (VUT13,200). Although the monetary return does not cover the minimum-wage hourly rate, the Paama community had already supplied 700 kg of kernels that year, suggesting that money is not the driving force. This is a socially engaging activity that brings the community together and provides women with some money to spend on household items, which they would otherwise not have had.

A domestication strategy recently developed for Vanuatu outlines 2 pathways to develop improved germplasm (Macdonell and Page 2022). The first uses thinned progeny trial(s) to supply improved seed, of which one trial was established on Espiritu Santo (Page et al. 2022b). The second pathway relies on developing asexual multiplication techniques. Several technical challenges remain with clonal multiplication of selected trees, plus the long maturation period until fruiting is preventing more rapid gains. Both pathways form the foundation for investigating the many knowledge gaps and ultimately achieving the goal of providing improved seed to smallholders and industrial plantations.

The impacts of domestication

The resources invested in the domestication of a species are often substantial in human and monetary terms. Being able to measure and record the benefits to end users is an important part of evaluating the impact of the research. In Melanesian countries, it can be difficult to keep formal records. Instead, anecdotal evidence is collected by interviewing relevant people and making observations. In addition, work on trees is a long-term venture in cycles that often extend beyond the timeframes of externally funded projects, making it challenging to compare theoretical gains against realised gains. Financial models have been developed for sandalwood (Ota et al. 2022c) and whitewood (Ota et al. 2022a), with a *Canarium* model in the final stages of development (Ota et al. 2022b). These models will inform growers of the upfront costs and the expected inputs required throughout the lifespan of the woodlot. The models provide default values for the planting density, labour requirements, cost of materials, age of harvest, the expected yield and the value of the end products based on current knowledge. Furthermore, the user can change any of these values to suit individual requirements and determine the financial viability of the change.

Sandalwood

With sandalwood domestication in Vanuatu, grafted seed orchards were established within community areas. The purpose was to enable locals to collect seed from the best available germplasm when establishing their own small plots. Establishing seed orchards in accessible locations and allowing any member of the community to collect seed is a way of distributing germplasm among the community, although recording the extent of this distribution can be problematic. The most reliable adoption figure was purported to be 100,000 seedlings distributed to projects throughout Vanuatu between 2008 and 2012, with half of these being attributed to ACIAR-supported projects (Davila et al. 2021). While gaining an accurate account of the number of seedlings derived from improved sources has proved challenging, the flow-on benefits of an active domestication initiative in terms of adoption cannot be underestimated. The wider distribution of sandalwood seedlings and adoption among smallholders is projected to see a tripling of the annual quota from 80 to 240 tonnes a year as the trees planted from 2008 to 2012 begin to mature (Davila et al. 2021). Thomson (2020) reported that the plantation area in 2014 approached 1,400 ha and projected that heartwood production from these sources is likely to be around 400 tonnes a year. In the most recent sandalwood season, the volumes harvested from planted stands approached 170 tonnes (DoF unpublished data set 2022), demonstrating the effectiveness of domestication efforts when considered in its broadest sense. The benefit:cost ratio of ACIAR investment in domestication and development of sandalwood in Vanuatu was calculated to be in excess of 5:1 (Davila et al. 2021). Page et al. (2012a) reported that a typical 1-ha sandalwood agroforestry system that incorporated sandalwood into a productive garden resulted in a benefit:cost ratio of over 2:1. Smallholders typically establish sandalwood plantings using their own equity, most notably labour. The internal rate of return (IRR) of 28% for sandalwood agroforestry calculated in a recent study by Ota et al. (2022c) was at the higher range of previous financial analyses on sandalwood plantations (16% to 28%) (Page et al. 2010a; Thomson et al. 2011). With many growers harvesting early (at 8 to 12 years) due to tree security issues and environmental risks, Ota et al. (2022c) calculated that this practice resulted in a 64% reduction in potential returns relative to the recommended rotation (15 to 20 years).

Figure 2-2: Whitewood plantation, Santo, Vanuatu

Whitewood

For whitewood with improved germplasm developed centrally on government land in association with communities, there is evidence of smallholder adoption at 100 ha per year where there was government-supported seedling distribution (Walker 2015). While this level of adoption is encouraging, even greater dissemination of whitewood may be possible with additional government support for nursery consumables. Walker (2015) suggested that smallholder-compatible, low-technology nursery systems could further increase adoption if the cost of polybags were subsidised. Further improvements could involve upgrading the whitewood value chain and a more deliberate geographical planning of the distribution of seedlings to ensure a concentration of woodlots is established (Carias et al. 2022; Ota et al. 2022a). At the end of 2018, the volume of merchantable smallholder-grown whitewood ready for harvest over the ensuing 2 years was estimated at almost 10,600 cubic metres (Carias et al. 2022). A financial analysis of smallholder-grown whitewood showed that break-even prices were higher than current prices paid for native harvest. Collective sales can be financially viable if buyers can accommodate a price increase of 7% to 16% for larger volumes and more consistent supply (Ota et al. 2022a).

Canarium nut

The pathway towards growing the smallholder-based *Canarium* industry in Melanesia has mostly occurred through utilisation and marketing, such as connecting growers with processors and taking steps to address consumer demand (Wallace et al. 2021). While many households in PNG had already been selling small quantities at local markets, a supply chain of over 1,300 smallholders has been created in recent years. Combined, they sold 207 tonnes of fruit in 2018 and more than 300 tonnes in 2019 to a pilot factory and 4 commercial processing companies that had been set up in 2019 as a direct result of the project's success (Wallace et al. 2021). Installation and testing of mechanical processing equipment resulted in a fourfold increase of processed product per day. Kernel roasting and storage trials developed methods that retained kernel quality for at least 12 months and satisfied product quality requirements of commercial retail outlets (Wallace et al. 2021).

Government interventions have supported seedling distribution to increase the number of trees and their spatial concentration (Carter and Smith 2016). In PNG, *Canarium* seedlings have been distributed together with cocoa seedlings (PPAP 2017) and the development of *Canarium* as a commercial crop has been promoted through its compatibility as a low-maintenance shade tree in smallholder cocoa systems (Wallace et al. 2021). In PNG, the deployment of improved germplasm for grower adoption has focused on the provenance from Nissan island, based on its very large kernel size (Cornelius et al. 2012).

Notwithstanding the great potential for the *Canarium* nut industry, a financial analysis of production in Vanuatu revealed challenges. The significant labour required for fruit processing and nut cracking limits the financial viability of smallholder production when labour is costed at minimum wage (net present value (NPV) of US$13,972, at a 10% discount rate) (Ota et al. 2022b). Village-scale mechanical crackers are yet to be broadly adopted since smallholders considered the cost of capital to be excessive (Wallace et al. 2021). Despite this, many smallholders remain engaged in commercial nut production and the non-financial returns, such as socially engaging group harvesting and processing, may offset the financial challenges of the current production system. Plus, women may be benefiting from the extra cash that they would otherwise not have access to. When the cost of labour is excluded from the financial analysis, the NPV is US$8,072 (10% discount rate) (Ota et al. 2022b). In PNG, industrial mechanical crackers can produce one tonne of *Canarium* nuts per day (Wallace et al. 2021). Given that break-even analysis for nut-in-shell production (US$0.263/kg) was within the price range (US$0.20 to US$0.50/kg) reviewed by Grant et al. (2022), the efficiencies achieved through industrial processing can promote financially viable smallholder *Canarium* production.

Economic benefits of domestication

Quantifying the broader economic benefits of domestication is important to justify the investment in the research and development. We modelled the economic impact of 1,000 households, adopting each of the 3 crops and comparing the value returned at the household level and estate level when seedlings were derived from improved sources compared with unselected stock (Table 2-2). In the model, each household established a small number of trees so that by the end of the rotation they maintained a 1-ha planting. It was assumed that through cooperation among growers a level of resource aggregation took place. For *Canarium* planted at wide spacing (9 m × 9 m), the planting of 24 trees per year over 5 years achieved an area of 1 ha. For sandalwood and whitewood, an annual household planting rate of 20 trees (5 m × 5 m) and 42 trees (3 m × 4 m), respectively, over 20 years was assumed.

Canarium

The *Canarium* model assumed the crop was harvested annually between years 5 and 20, with an average kernel yield of 19.5 kg/tree/year (a 30% increase on the average yield of 15 kg/tree/year as reported by Nevenimo et al. (2007)). The level of gain was drawn from existing information on *Canarium* and we based a 30% increase in yield on the assumption that the best *Canarium* families are between 24% and 36% superior to the provincial means (Cornelius et al. 2012). In 2020, the farm-gate price for kernels in PNG was US$4.20 to US$5.60/kg (15–20 Papua New Guinean kina (PGK)) (Wallace et al. 2021). The annual household income from the sale of *Canarium* kernels from improved sources is US$9,555. Annual farm-gate income across the entire *Canarium* estate (1,000 households) is US$2.2 million greater when using improved stock (US$9.5 million) compared with unimproved (US$7.3 million) stock. In PNG, the kernel retail value in 2021 was found to be US$40/kg (PGK140–170) (Wallace et al. 2021). Using a more conservative retail price of US$10/kg, the annual retail value is US$19.5 million compared with US$15 million for unimproved stock.

Table 2-2: **The modelled economic impact of 1,000 households each adopting 1 ha of sandalwood, whitewood and *Canarium*. The value returned is shown at the household level and the estate level, as is the value of using seedlings derived from improved stock and unimproved stock.**

			Species					
	Variable	Unit of measure	Sandalwood		Whitewood		Canarium	
Planting stocks	Planting rate	trees/year		20		42		24
	Planting rate (final crop trees)	trees/year		20		13.3		24
	Initial spacing			5 m × 5 m		4 m × 3 m		9 m × 9 m
	Initial stocking	trees/ha		400		833		120
	Final stocking rates	trees/ha		400		266		100
Production	First year products sold			21		21		6
	Product sold			Heartwood		Final crop sawlogs		Kernels
	Units of production			kg		m^3		tonne
			Unimproved	Improved	Unimproved	Improved	Unimproved	Improved
	Mean product tree size at harvest	units/tree	18	20	1.125	1.725	0.015	0.0195
	Volume at harvest	units/smallholder plot	360	400	15	23	0.30	0.39
	Annual product flow from 1,000 smallholders	units/year	360,000	400,000	15,000	23,000	360	468
Gross returns	Unit price at farm gate	US$/unit	28	33	40	40	4,900	4,900
	Mean tree returns at farm gate	US$/tree	498	656	45	69	74	96
	Household farm-gate returns at harvest	US$/household/year	9,954	13,120	600	920	7,350	9,555
	Crop returns at harvest	US$/ha	199,080	262,400	12,000	18,400	7,350	9,555
Estate (1,000 smallholders @ 1 ha each)	Annual production	tonnes (or m^3) /year	360	400	15,000	23,000	1,500	1,950
	Estate farm-gate returns	US$/year	9,954,000	13,120,000	600,000	920,000	7,350,000	9,555,000
	Estate contribution to export/retail at harvest	US$/year	19,908,000	26,240,000	3,000,000	4,600,000	15,000,000	19,500,000
	Estate retail/export value over its 20-year life	US$	398,160,000	524,800,000	60,000,000	92,000,000	15,000,000	19,500,000
Present value of gross project returns	Gross present value smallholder returns discounted at 10% real	US$/household	9,464	12,474	570	875	128,593	167,171
		US$/estate	9,464,055	12,474,222	570,467	874,717	128,592,692	167,170,500
	Gross present value smallholder export/retail contribution discounted at 10% real	US$/household	18,928	24,948	2,852	4,374	262,434	341,164
		US$/estate	18,928,111	24,948,444	2,852,337	4,373,584	262,434,066	341,164,286

Sandalwood

The sandalwood model assumed that the higher quality trees will attract a price premium at both farm gate and at export. In 2019, the farm-gate pricing structure in Fiji was US$45 (100–150 Fijian dollars (FJD)), US$32 (FJD70–90) and US$14 (FJD30–50) for the butt, logs and small pieces respectively (Bolatolu et al. 2021). Through generalised modelling of the benefits associated with improved sandalwood, it can be expected that at least 20% will be graded as first-grade butts, 70% will be second-grade logs and 10% will be third-grade pieces. For unimproved stock, it is expected to be closer to 15% first grade, 50% second grade and 35% third grade. This is combined with an expected minimum 10% increase in heartwood yield for improved stock (18 kg/tree for unimproved and 20 kg/tree for improved stock at 20 years). Annual household income from the sale of 20 mature trees per year is US$13,120 for improved stock and US$9,954 for unimproved stock. With an overall annual production of 400 and 360 tonnes of heartwood for improved and unimproved trees, respectively, this equates to an export value of US$26 million and US$20 million, respectively.

Whitewood

For whitewood, we project an increase in mean annual increment in wood volume from 15 to 23 m^3/ha/year when using improved material (Page et al. 2017). A planting in Vanuatu expanding at 50 ha/year for 20 years, growing at 23 m^3/ha/year, provides an annual yield of 1,150 m^3 upon maturity. At a farm-gate price of US$40/m^3 (VUV4,400), this equates to an annual income of close to US$900 (VUV99,000) per household for the sale of 13 mature trees. The mean annual wage of about 55% of Vanuatu's employed is US$2,180 to US$6,545 (VUV240,000–720,000) (VNSO 2021:41), so the income equates to 1.65 to 5 months' salary. The recovery of saleable lumber is 50% and, based on current imported pricing and the results of research (Viranamangga 2013), the average retail price of whitewood sawn timber products is about US$400/m^3 (VUV44,000). This results in an annual gross return to the economy of US$4.6 million when using improved material, and US$3 million when using unimproved material.

Figure 2-3: ***S. macgregorii*** **mixed planting at Eboa village, Kairiku, Central province, PNG**

Key findings

The domestication process of a species needs to be adaptable and realistic at the local level. While many species have been identified as potential candidates for domestication (Table 2-1), it is not until a shortage is experienced that the need for domestication is perceived – unfortunately, for some species, after significant loss of genetic diversity has occurred. Sandalwood and whitewood were over-exploited in the wild and failure to act would have resulted in further permanent loss of diversity and contraction of both industries. Intervention has provided the opportunity to improve the end products through tree breeding, with prosperous sandalwood industries emerging in PNG, Vanuatu and Fiji. Whitewood is in the early stages of recovery, with farmers gradually establishing a new resource base from improved seed sources. Although *Canarium* has a large natural resource base, its shortage arose from a labour shortage, with people moving away from villages to populated areas. The challenges in fulfilling the high demand for *Canarium* nuts have been the significant labour inputs associated with non-mechanised nut processing, post-processing storage issues, and marketing.

Summary of insights

- Evaluating the impact of tree improvement activities in Pacific countries is difficult as few accurate records are kept and scientific trials often do not mature within the time frame of individual projects.
- Financial models can give growers the knowledge to make informed decisions on the overall investment required to produce commercial products.
- Grower financial returns and wider economic benefits are enhanced when improved germplasm for the 3 focal species is used as the basis for a smallholder woodlot.
- Developing and distributing grower guides and other information generated through projects can empower farmers to manage their trees in a way that will maximise returns.
- Domestication is much more than just tree breeding. It is any activity that improves the utilisation of the species.

References

Addinsall C, Glencross K, Rihai N, Kalomor L, Palmer G, Nichols D, Smith G (2016) 'Enhancing agroforestry in Vanuatu: striking the balance between individual entrepreneurship and community development', *Forests, Trees and Livelihoods*, 25:78–96.

Agiwa A and Uwamariya A (2004) '*Casuarina oligodon*' in Gunn B, Agiwa A, Bosimbi D, Brammall B, Jarua L and Uwamariya A (eds) *Seed handling and propagation of Papua New Guinea's tree species and forest products*, CSIRO Forestry and Forest Products, Canberra, p. 36–37.

Almeida L, Page T, Williams R, Hettiarachchi D, Boyce M, Erskine W, Sacaio M, Alves AP, Patrocinio LC, Pereira I and Cristovão JJ (2022) *Morphology, heartwood and essential oil phytochemistry in sandalwood (*Santalum album *L.) of Timor-Leste* [a report for the Timor-Leste Ministry of Agriculture and Fisheries, Al-Com, The University of Western Australia and University of the Sunshine Coast], Ministry of Agriculture and Fisheries, Dili, Timor-Leste.

Anyonge CH and Roshetko JM (2003) 'Farm-level timber production: orienting farmers towards the market', *Unasylva*, 3:48–56.

Arnold RJ (2018) '*Acacia mangium*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, p. 42–45.

Arnold RJ and Luo J (2018) '*Eucalyptus camaldulensis*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 94–99.

Aru R, Nichols JD, Grant JC, Leys AJ, Glencross K, Sethy M, Convery K and Viranamangga R (2012) 'Constraints to whitewood (*Endospermum medullosum*) plantation development on Santo Island, Vanuatu', *International Forestry Review*, 14:414–423.

Ataia A (1983) '*Casuarina oligodon* in the Eastern Highlands Province - Papua New Guinea' in Midgley SJ, Turnbull JW and Johnson RD (eds) *Proceedings of an international Casuarina workshop*, Melbourne, CSIRO, p. 80–88.

Boland DJ and Thomson LA (30–31 March 1999) 'SPRIG: a regional forest genetic resource R&D aid project in the South Pacific' [paper presented at an ACIAR–NARI workshop], Lae, Papua New Guinea (not published).

Bolatolu W, Lesubula M and Vukialau M (2021) 'Sandalwood development in Fiji', in Page T, Meadows J and Kalsakau T (eds) *Sandalwood regional forum: Proceedings of a regional meeting held in Port Vila, Vanuatu 11–13 November 2019*, ACIAR Proceedings, No. 150, Australian Centre for International Agricultural Research, Canberra, Australia, p. 9–20.

Bolesta A (2020) *Asia-Pacific small island developing states: development challenges and policy solutions*, Macroeconomic Policy and Financing for Development Division, ESCAP (Economic and Social Commission for Asia and the Pacific), United Nations, Bangkok.

Bond A (2006) *Pacific 2020: Background Paper – Forestry*, AusAID, Canberra.

Bourdeix R and Batugal P (2018) '*Cocos nucifera* (with a focus on Oceania)', in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 81–85.

Bourke RM (2009a) 'Cash income from agriculture', in Bourke RM and Harwood T (eds) *Food and agriculture in Papua New Guinea*, ANU Press, Canberra, Australia, p. 283–424.

—— (2009b) 'History of agriculture in Papua New Guinea', in Bourke RM and Harwood T (eds) *Food and agriculture in Papua New Guinea*, ANU Press, Canberra, Australia, p. 10–26.

—— (2018) 'Half a century of agricultural development in Papua New Guinea: A didiman reflects', in Thomas P (ed) *Development bulletin No. 80. Pacific reflections: personal perceptions of aid and development*, The Development Studies Network, Australian National University, Canberra, p. 25–29.

Brown RPC, Connell J and Jimenez-Soto EV (2014) 'Migrants' remittances, poverty and social protection in the South Pacific: Fiji and Tonga', *Population Space and Place*, 20:434–454.

Bunt C and Leakey RRB (2008) 'Domestication potential and marketing of *Canarium indicum* nuts in the Pacific: commercialization and market development', *Forests, Trees and Livelihoods*, 18:271–289.

Burley J and Kanowski PJ (2005) 'Breeding strategies for temperate hardwoods', *Forestry*, 78:199–208.

Bush D, Bolatolu W, Clarke B, Likiafu H, Mateboto J and Thomson L (2021) *Domestication and breeding of sandalwood in Fiji and Tonga*, Australian Centre for International Agricultural Research, Canberra, Australia.

Bush D, Brophy J, Bolatolu W, Dutt S, Hamani S, Doran J and Thomson LAJ (2020a) 'Oil yield and composition of young *Santalum yasi* in Fiji and Tonga', *Australian Forestry*, 83:238–244.

Bush D, Pinyopusarerk K, Zhang Y, Hu P and Zhong C (2020b) 'Population structure and diversity of *Casuarina equisetifolia* – results from 25 years of research', in Haruthaithanasan M, Pinyopusarerk K, Nicodemus A, Bush D and Thomson L (eds) *Proceedings of the sixth international Casuarina workshop: casuarinas for green economy and environmental sustainability, Casuarina 2019*, Krabi, Thailand, 21–25 October 2019, p. 128–135.

Bush D, Thomson L, Broadhurst L, Dutt S, Bulai P, Faka'osi T, Havea M, Napa'a S and Vainikolo L (2016) *Assessing genetic diversity of natural and hybrid populations of* Santalum yasi *in Fiji and Tonga*, Australian Centre for International Agricultural Research, Canberra, Australia.

Bush D, Thomson LAJ, Dutt S, Hamani S, Bolatolu W, Tauraga J, Mateboto J and Young E (2020c) 'Domestication provides the key to conservation of *Santalum yasi* – a threatened Pacific sandalwood', *Australian Forestry*, 83:186–194.

Campbell MM, Brunner AM, Jones HM and Strauss SH (2003) 'Forestry's fertile crescent: the application of biotechnology to forest trees', *Plant Biotechnology Journal*, 1:141–154.

Carias D, Page T, Smith H, Race D, Keenan RJ, Palmer G and Baynes J (2022) 'Beyond the "Field of Dreams" model in smallholder forestry: building viable timber value chains for smallholder tree growers in developing countries', *Land Use Policy*, 120:106227.

Carias D, Ota L, and Page T (2023) 'Challenges and opportunities for inclusive value chains of forest products in small island developing states: canarium nuts, sandalwood, and whitewood in Vanuatu', *Journal of Rural Studies*, 100:103036.

Carter J and Smith EF (2016) 'Spatialising the Melanesian Canarium industry: understanding economic upgrading in an emerging industry among three Pacific small island states', *Geoforum*, 75:40–51.

Ceccarelli S and Grando S (2007) 'Decentralized-participatory plant breeding: an example of demand driven research', *Euphytica*, 155:349–360.

Chazdon R and Brancalion P (2019) 'Restoring forests as a means to many ends', *Science*, 365:24.

Cheer JM, Pratt S, Tolkach D, Bailey A, Taumoepeau S and Movono A (2018) 'Tourism in Pacific island countries: a status quo round-up', *Asia & the Pacific Policy Studies*, 5:442–461.

Clark WC (1993) 'Agroforestry in Melanesia: case-studies from Papua New Guinea and the Solomon Islands', in Clark WC and Thaman RR (eds) *Agroforestry in the Pacific Islands: systems for sustainability*, United Nations University Press, p. 35–41.

Connell J (2007) 'Towards free trade in the pacific? the genesis of the 'Kava-Biscuit war' between Fiji and Vanuatu', *Geographical Research*, 45:1–12.

Connell J (2010) 'Pacific islands in the global economy: paradoxes of migration and culture', *Singapore Journal of Tropical Geography*, 31:115–129.

Cornelius J, Nevenimo T, Minnah S, Sibaris W, Yagau K, Leakey R, Page T and Pauku R (2012) *Domestication and commercialisation of* Canarium indicum *in Papua New Guinea*, Australian Centre for International Agricultural Research, Canberra, Australia.

Corrigan H, Naupa S, Likiafu R, Tungon J, Sam C, Viji I, Sam C, Kalamor L, Mele L, Walker S, Collins S and Thomson L (2000) *A strategy for conserving, managing & better utilizing the genetic resources of* Endospermum medullosum *(whitewood) in Vanuatu*, South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), Canberra, Australia, and Vanuatu Department of Forests, Port Vila, Vanuatu.

Davidson J, Gunn B and Spencer D (2004) '*Eucalyptus deglupta*', in Gunn B, Agiwa A, Bosimbi D, Brammall B, Jarua L and Uwamariya A (eds) *Seed handling and propagation of Papua New Guinea's tree species and forest products*, CSIRO Forestry and Forest Products, Canberra, p. 104–107.

Davila F, Vanzetti D and Sloan T (2021) *Mixed-methods impact assessment of sandalwood research in Vanuatu*, Australian Centre for International Agricultural Research, Canberra, Australia.

Del Lungo A, Ball J and Carle J (2006) *Global planted forests thematic study: results and analysis*, Planted forests and trees working paper 38, Food and Agriculture Organization of the United Nations, Rome, Italy.

Doran J, Bush D, Page T, Glencross K, Sethy M and Viji I (2012) 'Variation in growth traits and wood density in whitewood (*Endospermum medullosum*): a major timber species in Vanuatu', *International Forestry Review*, 14:476–485.

Doran J, Page T, Tungon J and Tate H (2021a) 'Participatory domestication strategy for Vanuatu sandalwood', in Page T, Meadows J and Kalsakau T (eds) *Sandalwood Regional Forum: proceedings of a regional meeting held in Port Vila, Vanuatu 11–13 November 2019*, ACIAR Proceedings, No. 150, Australian Centre for International Agricultural Research, Canberra, Australia, p. 160–194.

Doran J, Viranamangga R, Sethy M and Page T (2021b) *Participatory domestication strategy for whitewood* (Endospermum medullosum) *in Vanuatu*, Report for ACIAR project FST/2016/154 'Enhancing returns from high-value agroforestry species in Vanuatu', Australian Centre for International Agricultural Research, Canberra, Australia.

Dvorak WS, Gutierrez EA, Hodge GR, Romero JL, Stock J and Rivas O (2000) '*Pinus caribaea* var. *hondurensis*', in (eds) *Conservation and testing of tropical and subtropical forest tree species by the CAMCORE Cooperative*, CAMCORE Cooperative, NC State University, Raleigh, NC, p. 12–33.

Eldridge KG, Davidson J, Harwood J and Van Wyk G (1993a) *Eucalypt domestication and breeding*, Clarendon Press, Oxford, UK.

—— (1993b) '*Eucalyptus deglupta*', in Eldridge KG, Davidson J, Harwood J and Van Wyk G (eds.) *Eucalypt domestication and breeding*, Clarendon Press, Oxford, UK.

Elevitch CR and Ragone D (2018) *Breadfruit agroforestry guide: planning and implementation of regenerative organic methods*, Breadfruit Institute of the National Tropical Botanical Garden, Kalaheo, Hawaii, and Permanent Agricultural Resources, Holualoa, Hawaii, USA.

Ellen R (2019) 'Ritual, landscapes of exchange, and the domestication of *Canarium*: a Seram case study', *Asian Perspectives: The Journal of Archaeology of Asia and The Pacific*, 58(2):261–286.

Evans BR (1991) *A variety collection of edible nut tree crops in Solomon Islands*.: Research Bulletin No. 8. Dodo Creek Research Station, Ministry of Agriculture and Lands, Honiara, Solomon Islands.

Evans BR (1999a) *Edible nut trees in Solomon Islands: a variety collection of* Canarium, Terminalia *and* Barringtonia, Australian Centre for International Agricultural Research, Canberra, Australia.

Evans BR (1999b) *Natapoa (*Terminalia catappa*) seed collection, Vanuatu*, Report prepared for SPRIG project, South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), Canberra, Australia.

Evans J (2009) *Planted forests: uses, impacts and sustainability*, CABI, Wallingford, UK.

FAO (1979) *Poplars and willows in wood production and land use*, Food and Agriculture Organization of the United Nations, Rome, Italy.

—— (2019) *Forest futures – sustainable pathways for forests, landscapes and people in the Asia-Pacific region*, Food and Agriculture Organization of the United Nations, Bangkok, Thailand.

Fargher J, Duthie R and Vagikapi M (2018) *Pacific horticultural and agricultural market access (PHAMA) plus*, Investment design document for the Australian Government Department of Foreign Affairs and Trade, Australian High Commission, Fiji.

Fenning TM and Gershenzon J (2002) 'Where will the wood come from? plantation forests and the role of biotechnology', *Trends in Biotechnology*, 20:291–296.

Galindo-Tovar ME, Ogata-Aguilar N and Arzate-Fernández AM (2008) 'Some aspects of avocado (*Persea americana* Mill.) diversity and domestication in Mesoamerica', *Genetic Resources and Crop Evolution*, 55:441–450.

Gibbs HK, Ruesch AS, Achard F, Clayton MK, Holmgren P, Ramankutty N and Foley JA (2010) 'Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s', *Proceedings of the National Academy of Sciences*, 107:16732–16737.

Glencross K and Viranamangga R (2012) *Silviculture of whitewood (*Endospermum medullosum*) in Vanuatu*, Australian Centre for International Agricultural Research, Canberra, Australia.

Grant E, Page T, Tungon J, Tabi M, Hannett D, Hannett G, Hodges B, Hosseini Bai S, Johns C, Jones K, Kalotap J, Kalsakau T, Kill E, Komolong B, Macdonell P, McNeice W, Nevenimo T, Sarisets A-M, Randall B and Wallace H (2022) 'Canarium production manual' for ACIAR project FST/2016/154, Australian Centre for International Agricultural Research, Canberra, Australia, not published.

Grant E, Macdonell P, Tungon J, Tabi M, David M, Kaku S and Page T (2023) 'Geographical variation in *Canarium indicum* (Burseraceae) nut characteristics across Vanuatu', *Genetic Resources and Crop Evolution*, doi:10.1007/s10722-023-01694-6.

Graudal L and Møestrup S (2017) 'The genetic variation in natural and planted teak forests: characterisation, use and conservation for the future', in Kollert W, Kleine M (eds) *The global teak study: analysis, evaluation and future potential of teak resource*, International Union of Forest Research Organizations, World Series Volume 36:19–29.

Haberle SG (2007) ‘Prehistoric human impact on rainforest biodiversity in highland New Guinea’, *Philosophical Transactions of the Royal Society B: Biological Sciences*, 362:219–228.

Harfouche A, Meilan R, Kirst M, Morgante M, Boerjan W, Sabatti M and Scarascia Mugnozza G (2012) ‘Accelerating the domestication of forest trees in a changing world’, *Trends in Plant Science*, 17:64–72.

Harlan JR (1971) ‘Agricultural origins: centers and noncenters’, *Science*, 174:468–474.

Harrison SR and Herbohn JL (2000) ‘The role of small-scale forestry throughout the world’, in Harrison SR, Herbohn JL and Herbohn KF (eds) *Sustainable small-scale forestry*, Edward Elgar, Cheltenham, UK, p. 3–13.

Harwood C (2018) ‘*Eucalyptus pellita*’, in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 108–111.

Henders S, Persson U and Kastner T (2015) ‘Trading forests: land-use change and carbon emissions embodied in production and exports of forest-risk commodities’, *Environmental Research Letters*, 10:125012.

Henderson CP and Hancock IR (1988) *A guide to the useful plants of Solomon Islands*, Ministry of Agriculture and Lands, Honiara, Solomon Islands.

Hong LT, Ramanatha Rao V and Chung RCK (2018) ‘*Syzygium malaccense*’, in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 217–219.

Howes S and Surandiran S (16 November 2020) ‘Pacific remittances: holding up despite COVID-19’, DevPolicyBlog, accessed 11 September 2023.

Jansen M, Guariguata MR, Raneri JE, Ickowitz A, Chiriboga-Arroyo F, Quaedvlieg J and Kettle CJ (2020) ‘Food for thought: The underutilized potential of tropical tree-sourced foods for 21st century sustainable food systems’, *People and Nature*, 2:1006–1020.

Jarua L and Uwamariya A (2004) ‘*Terminalia kaernbachii* Warb’, in Gunn B, Agiwa A, Bosimbi D, Brammall B, Jarua L and Uwamariya A (eds) *Seed handling and propagation of Papua New Guinea’s tree species and forest products,* CSIRO Forestry and Forest Products, Canberra, p. 68–69.

Johns RJ (1991) ‘*Terminalia kaernbachii* Warburg’, in Verheij EWM and Coronel RE (eds) *Plant resources of South-East Asia No 2: edible fruits and nuts*, PROSEA Foundation, Bogor, Indonesia.

Jones C (2012) *Weaving niche production into Pacific economies: the social, economic and environmental impacts of Fiji Water on local communities*, master’s thesis, Victoria University of Wellington, New Zealand.

Kanowski P, Holzknecht H and McGregor A (2014) *The potential of incorporating high-value tree species in Papua New Guinea agroforestry systems to enhance landowner livelihoods*, Final report for ACIAR project FST/2005/050, Australian Centre for International Agricultural Research, Canberra, Australia.

Kennedy J (2012) ‘Agricultural systems in the tropical forest: a critique framed by tree crops of Papua New Guinea’, *Quaternary International*, 249:140–150.

Keppel G, Thomson LAJ and Senivasa E (2018) ‘*Agathis macrophylla*’, in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 52–54.

Kirch P (1989) ‘Second millennium B.C. arboriculture in Melanesia: archaeological evidence from the Mussau Islands’, *Economic Botany*, 43:225–240.

Kumar NN and Patel A (2021) ‘Modelling the impact of COVID-19 in small pacific island countries’, *Current Issues in Tourism*, 25(3):1–11.

Lata A, Damas K and Fazang K (2018) ‘*Gyrinops ledermannii* and *G. caudata*’ in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 133–135.

Leakey RRB (2019) ‘From ethnobotany to mainstream agriculture: socially modified Cinderella species capturing “trade-ons” for “land maxing”’, *Planta*, 250:949–970.

Leakey RRB, Fuller S, Treloar T, Stevenson L, Hunter D, Nevenimo T, Binifa J and Moxon J (2008) ‘Characterization of tree-to-tree variation in morphological, nutritional and chemical properties of *Canarium indicum* nuts’, *Agroforestry Systems*, 73:77–87.

Leakey RRB and Simons AJ (1998) ‘The domestication and commercialization of indigenous trees in agroforestry for the alleviation of poverty’, *Agroforestry Systems*, 38:165–176.

Leakey RRB and Tchoundjeu Z (2001) 'Diversification of tree crops: domestication of companion crops for poverty reduction and environmental services', *Experimental Agriculture*, 37:279–296.

Leakey RRB, Weber JC, Page T, Cornelius JP, Akinnifesi FK, Roshetko J, Tchoundjeu Z and Jamnadass R (2012) 'Tree domestication in agroforestry: progress in the second decade (2003–2012)', in Nair PKR and Garrity D (eds) *Agroforestry - the future of global land use*, Springer, Berlin, p. 145–174.

Lee DJ, Burridge AJ, Page T, Huth JR and Thompson N (2019) 'Domestication of northern sandalwood (*Santalum lanceolatum*, Santalaceae) for Indigenous forestry on the Cape York Peninsula', *Australian Forestry*, 82:1–9.

Lepofsky D (1992) 'Arboriculture in the Mussau Islands, Bismark Archipelago', *Economic Botany*, 46:193–211.

Macdonell P (2018) Canarium *natural population survey, 2018, FR/PM/2018-12*, Field report for ACIAR project FST/2016/154 'Enhancing returns from high-value agroforestry species in Vanuatu', Australian Centre for International Agricultural Research, Canberra, Australia.

Macdonell P and Baskorowati L (2018) '*Falcataria moluccana*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 116–118.

Macdonell P and Page T (2022) *Domestication strategy for* Canarium indicum *in Vanuatu*, Report for ACIAR project FST/2016/154 'Enhancing returns from high-value agroforestry species in Vanuatu', Australian Centre for International Agricultural Research, Canberra, Australia.

Martin MP, Woodbury DJ, Doroski DA, Nagele E, Storace M, Cook-Patton SC, Pasternack R and Ashton MS (2021) 'People plant trees for utility more often than for biodiversity or carbon', *Biological Conservation*, 261:109224.

Matthews PJ, Gosden C (1997) 'Plant remains from waterlogged sites in the Arawe Islands, West New Britain Province, Papua New Guinea: implications for the history of plant use and domestication', *Economic Botany*, 51:121–133.

Mayhew JE and Newton AC (1998) *The silviculture of mahogany*, CABI Publishing, Wallingford, UK.

McClatchey W, Sirikolo MQB, Kaleveke L and Pitanapi C (2006) 'Differential conservation of two species of *Canarium* (Burseraceae) among the Babatana and Ririo of Lauru (Choiseul), Solomon Islands', *Economic Botany*, 60:212–226.

Midgley SJ, Stevens PR and Arnold RJ (2017) 'Hidden assets: Asia's smallholder wood resources and their contribution to supply chains of commercial wood', *Australian Forestry*, 80:10–25.

Midgley SJ and Thomson LAJ (2018) '*Acacia crassicarpa*', in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 35–38.

Midgley SJ and Turnbull JW (2003) 'Domestication and use of Australian acacias: case studies of five important species', *Australian Systematic Botany*, 16:89–102.

Morgan W (2013) 'Growing island exports: high value crops and the future of agriculture in the Pacific', Crawford School research paper no. 05/2013, *SSRN Electronic Journal*, doi:10.2139/ssrn.2371452.

Morton JF (1985) 'Indian almond (*Terminalia catappa*), salt-tolerant, useful, tropical tree with "nuts" worthy of improvement', *Economic Botany*, 39:101–112.

Morton JF (1987) 'Ambarella', in Morton JF (ed) *Fruits of warm climates*, JF Morton, Miami, Florida, USA, p. 240–242.

Naidu V (2010) 'Modernisation and development in the South Pacific', in Jowitt A and Newton T (eds) *Passage of change: law, society and governance in the Pacific*, ANU Press, Canberra, Australia, p. 7–31.

Nevenimo T, Moxon J, Wemin J, Johnston M, Bunt C and Leakey RRB (2007) 'Domestication potential and marketing of *Canarium indicum* nuts in the Pacific: 1. A literature review', *Agroforestry Systems*, 69:117–134.

Ngoro M, Zekele P, Denmark N, Spencer D and Clarke B (2006) *SPRIG Phase 2 Report on Field Activities in the Solomon Islands (Year 4, Quarter 4)*, South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), Canberra, Australia.

Nichols JD and Vanclay JK (2012) 'Domestication of native tree species for timber plantations: key insights for tropical island nations', *International Forestry Review*, 14:402–413.

Nicodemus A, Mayavel D, Bush D and Pinyopusarek K (2020) 'Increasing productivity of casuarina plantations in India through genetically improved seeds and clones', in Haruthaithanasan M, Pinyopusarerk K, Nicodemus A, Bush D and Thomson L (eds) *Proceedings of the sixth international Casuarina workshop: casuarinas for green economy and environmental sustainability, Casuarina 2019*, Krabi, Thailand 21–25 October 2019, p. 105–116.

Nikles DG and Arnold RJ (2018) '*Araucaria cunninghamii*', in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 55–59.

Nurse K (2016) *Dynamic trade policy for small island developing states*, International Trade Working Paper, Commonwealth Secretariat, London.

Olsen KM and Wendel JF (2013) 'A bountiful harvest: genomic insights into crop domestication phenotypes', *Annual Review of Plant Biology*, 64:47–70.

Ota L, Page T, Carias D, Palmer G, Viranamangga R and Kaku S (2022a) *Making whitewood tree growing financially attractive to smallholders in Vanuatu*, Report for ACIAR project FST/2016/154 'Enhancing returns from high-value agroforestry species in Vanuatu', Australian Centre for International Agricultural Research, Canberra, Australia.

Ota L, Page T, Grant E, Carias D, Macdonell P, Tungon J and Tabi M (2022b) *Canarium nuts for supplementary household income in Vanuatu*, Report for ACIAR project FST/2016/154 'Enhancing returns from high-value agroforestry species in Vanuatu', Australian Centre for International Agricultural Research, Canberra, Australia.

Ota L, Page T, Vira R, Kalsakau T and Herbohn J (2022c) 'How financially viable is smallholder forestry? a case study with a high-value tropical forestry species', *Small-Scale Forestry*, 21:505–525.

Page T, Bottin L, Bouvet J-M and Tate H (2018) '*Santalum austrocaledonicum*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 200–204.

Page T, Bush D, Sethy M and Doran J (2017) 'Variation in early growth in a second-generation whitewood (*Endospermum medullosum*) progeny trial in Vanuatu', *Australian Forestry*, 80:121–126.

Page T, Clarke B, Bush D and Thomson LAJ (eds) (2022a) *Pacific sandalwood: growers' guide for sandalwood production in the Pacific region*, Australian Centre for International Agricultural Research, Canberra, Australia.

Page T and Doran J (2021) 'Product specifications for tropical planted sandalwood to facilitate transparent commerce and trade', in Page T, Meadows J and Kalsakau T (eds) *Sandalwood Regional Forum: proceedings of a regional meeting held in Port Vila, Vanuatu 11–13 November 2019*, ACIAR Proceedings, No. 150, Australian Centre for International Agricultural Research, Canberra, Australia, p. 69–83.

Page T, Doran J, Tungon J and Tabi M (2020a) 'Restoration of Vanuatu sandalwood (*Santalum austrocaledonicum*) through participatory domestication', *Australian Forestry*, 83:216–226.

Page T, Jeffrey GK, Macdonell P, Hettiarachchi D, Boyce MC, Lata A, Oa L and Rome G (2020b) 'Morphological and heartwood variation of *Santalum macgregorii* in Papua New Guinea', *Australian Forestry*, 83:195–207.

Page T, Murphy ME, Mizrahi Mi, Cornelius JP and Venter M (2016) 'Sustainability of wood-use in remote forest-dependent communities of Papua New Guinea', *Forest Ecology and Management*, 382:88–99.

Page T, Palmer G, David M, Ota L, Carias D, Macdonell P, Doran J, Grant E, Viranamangga R, Kalsakau T, Kaku S, Tungon J and Tabi M (2022b) *Enhancing returns from high-value agroforestry species in Vanuatu,* Final report for ACIAR project FST/2016/154, Australian Centre for International Agricultural Research, Canberra, Australia.

Page T, Potrawiak A, Berry A, Tate H, Tungon J and Tabi M (2010a) 'Production of Sandalwood (*Santalum austrocaledonicum*) for improved smallholder incomes in Vanuatu', *Forests, Trees and Livelihoods*, 19:299–316.

Page T, Southwell I, Russell M and Leakey RRB (2007) 'Evaluation of heartwood and oil characters in seven populations of *Santalum lanceolatum* from Cape York', in Thomson L, Bulai S and Wilikibau B (eds) *Proceedings of the Regional Workshop on Sandalwood Research, Development and Extension in the Pacific Islands and Asia*, 28 November – 1 December 2005, Nadi, Fiji, p. 131–136, Secretariat of the Pacific Community, Nadi, Fiji, Australian Agency for International Development Assistance, German Agency for Technical Cooperation, ISBN 978-982-00-0196-1.

Page T, Southwell I, Russell M, Tate H, Tungon J, Sam C, Dickinson G, Robson K and Leakey RRB (2010b) 'Geographic and phenotypic variation in heartwood and essential oil characters in natural populations of *Santalum austrocaledonicum* in Vanuatu', *Chemistry and Biodiversity*, 7:1990–2006.

Page T, Tate H, Bunt C, Potrawiak A and Berry A (2012a) *Opportunities for the smallholder sandalwood industry in Vanuatu*. TR079, Australian Centre for International Agricultural Research, Canberra.

Page T, Tate H, Tungon J, Tabi M and Kamasteia P (2012b) *Vanuatu Sandalwood: growers' guide for sandalwood production in Vanuatu*, Australian Centre for International Agricultural Research, Canberra.

Paquette A and Messier C (2010) 'The role of plantations in managing the world's forests in the Anthropocene', *Frontiers in Ecology and the Environment*, 8:27–34.

Pauku R, Lowe A and Leakey RRB (2010) 'Domestication of indigenous fruit and nut trees for agroforestry in the Solomon Islands', *Forests, Trees and Livelihoods*, 19:269–287.

Pauku RL (2005) '*Inocarpus fagifer* (Tahitian chestnut)', in Elevitch CR (ed) *Species profiles for Pacific island agroforestry*, Permanent Agriculture Resources, Holualoa, USA.

—— (2006) '*Barringtonia procera* (cutnut)', in Elevitch CR (ed) *Species profiles for Pacific island agroforestry,* Permanent Agriculture Resources, Holualoa, USA.

Pedersen A and Gua B (2018) '*Tectona grandis*', in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 220–223.

Pinyopusarek K, Midgley SJ and Thomson LAJ (2018) '*Acacia auriculiformis*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, p. 28–30.

Pinyopusarerk K (2020) 'Four decades of international research and development in *Casuarinas*', in Haruthaithanasan M (ed) *Proceedings of the sixth international Casuarina workshop: casuarinas for green economy and environmental sustainability*, Krabi, Thailand 21–25 October 2019, p. 7–13.

Pinyopusarerk K and Midgley S (2018) '*Casuarina equisetifolia*', in: Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, p. 77–80.

Potts BM (2004) 'Genetic improvement of eucalypts', in Burley J (ed) *Encyclopedia of forest sciences*, Elsevier, Oxford, UK, p. 1480–1490.

Pouli MAT, Vigilu V and Thomson LAJ (2018) '*Flueggea flexuosa*' in Thomson L, Doran J and Clarke B (eds) *Trees for life in Oceania: conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, Australia, p. 119–121.

PPAP (Productive Partnerships in Agriculture Project) (2017) *Bi-annual report for the period 31st October 2016 to May 2017*, Cocoa Board of Papua New Guinea, Kokopo, Papua New Guinea, accessed 6 January 2023.

Race D and Wettenhall G (2016) *Adding value to the farmers' trees: experiences of community-based commercial forestry in Indonesia*, Australian Centre for International Agricultural Research, Canberra, Australia.

Randall B, Walton D, Nevenimo T, Poienou M, Moxon J, Hannet G and Wallace HM (2018) '*Canarium indicum*' in Thomson L, Doran J and Clarke B (eds) *Trees of life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Agricultural Research, Canberra, p. 73–76.

Randall BW, Walton DA, Grant EL, Zekele P, Gua B, Pauku R and Wallace HM (2016) 'Selection of the tropical nut *Canarium indicum* for early fruiting, nut-in-shell size and kernel size', *Acta Horticulturae*, 1109:169–173.

Rome G, Turia R, Oa L, Page T, Applegate G and Saliau C (2020) 'Sandalwood trade and development in Papua New Guinea', *Australian Forestry*, 83:208–215.

Roshetko J and Verbist B (2000) *Tree domestication*, Southeast Asia Lecture Note 6, World Agroforestry Centre - ICRAF, Bogor, Indonesia.

Sam C, Berry A, Gua B, Thomson LAJ and Pouru K (2002) *A plan for the conservation and sustainable utilization of* Canarium indicum *(Nangai or Ngali Nut) in Vanuatu and the Solomon Islands*, Secretariat for the Pacific Community, Suva, Fiji, and South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), Kingston, ACT, Australia.

Sauer CO (1952) *Agricultural origins and dispersals*, American Geography Society, New York.

Schirmer J, Pirard R and Kanowski P (2015) 'Promises and perils of plantation forestry', in Panwar R, Kozak R and Hansen E (eds) *Forests, business and sustainability*, Routledge, London, UK, p. 153–178.

Schreckenberg K, Awono A, Degrande A, Mbosso C, Ndoye O and Tchoundjeu Z (2006) 'Domesticating indigenous fruit trees as a contribution to poverty reduction', *Forests, Trees and Livelihoods*, 16:35–51.

Sederoff R, Myburg A and Kirst M (2009) 'Genomics, domestication, and evolution of forest trees', in Stillman B, Stewart D and Witkowski J (eds) *Evolution: the molecular landscape*, *74th Cold Spring Harbor Laboratory Symposium on Quantitative Biology*, p. 303–317, Cold Spring Harbor, NY.

Shearman P, Bryan J and Laurance WF (2012) 'Are we approaching 'peak timber' in the tropics?', *Biological Conservation*, 151:17–21.

Shen H and Li X (2021) 'From extensive collection to intensive cultivation, the role of fruits and nuts in subsistence economy on Chinese Loess Plateau', *Archaeological and Anthropological Sciences*, 13:61.

Silva LN, Freer-Smith P and Madsen P (2019) 'Production, restoration, mitigation: a new generation of plantations', *New Forests*, 50:153–168.

Simons AJ and Leakey RRB (2004) 'Tree domestication in tropical agroforestry', *Agroforestry Systems*, 61:167–181.

Smith A, Sethy M, Viji I and Robson K (2005) *Compilation report of field activities for Vanuatu*, Report prepared for South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) project, SPRIG, Canberra, Australia.

Stettler RF (2009) *Cottonwood and the river of time: on trees, evolution and society*, University of Washington Press, Seattle.

Tchoundjeu Z, Asaah EK, Anegbeh P, Degrande A, Mbile P, Facheux C, Tsobeng A, Atangana AR, Ngo-Mpeck ML and Simons AJ (2006) 'Putting participatory domestication into practice in west and central Africa', *Forests, Trees and Livelihoods*, 16:53–69.

Thomson L, Midgley S, Pinyopusarerk K and Kalinganire A (2002) 'Tree domestication: the Australian experience in partnerships with special reference to the Asia-Pacific region', in Thailand F-M (ed) *Proceedings of the Southeast Asian moving workshop on conservation, management and utilization of forest genetic resources*, Food and Agriculture Organization of the United Nations: FORSPA Publication No. 31/2002; p. 207–221.

Thomson L, Palmer G, Doran J, Viranamangga R (2018a) '*Endospermum medullosum'* in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 90–93.

Thomson LA (2006a) '*Endospermum medullosum* (whitewood)', in Elevitch CR (ed) *Traditional trees of Pacific Islands: their culture, environment and use,* Permanent Agriculture Resources, Holualoa, Hawaii, USA, p. 317–328.

—— (2006b) '*Flueggea flexuosa* (poumuli)', in Elevitch CR (ed) *Traditional trees of Pacific Islands: their culture, environment and use*, Permanent Agriculture Resources, Holualoa, Hawaii, USA, ISBN 0-9702544-5-8, p. 355–366.

—— (2006c) '*Santalum austrocaledonicum* and *S. yasi* (sandalwood) Santalaceae (sandalwood family)', in Elevitch CR (ed) *Traditional trees of Pacific Islands: their culture, environment and use*, Permanent Agriculture Resources, Holualoa, Hawaii, USA, ISBN 0-9702544-5-8, p. 675–694.

Thomson LAJ (2018a) '*Inocarpus fagifer*', in Thomson L, Doran J, and Clarke B (eds) *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 140–142.

—— (2018b) '*Pterocarpus indicus*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 192–195

—— (2020) 'Looking ahead – global sandalwood production and markets in 2040, and implications for Pacific Islands producers', *Australian Forestry*, 83:245–254.

Thomson LAJ, Bennett J and Doran JC (2018b) '*Calophyllum inophyllum*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 69–72.

Thomson LAJ, Bush D and Bulai P (2018c) '*Santalum yasi*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 210–213.

Thomson LAJ, Butaud J-F, Geraghty PA, Wilson WH and Mabberley DJ (2023) 'Breadfruit in the Pacific Islands, its domestication and origins of cultivars grown in East Polynesia and Micronesia', *Journal of South Pacific Agriculture*, 26:1–22.

Thomson LAJ, Doran J, Harbaugh D and Merlin MD (2011) *Farm and forestry production and marketing profile for sandalwood (*Santalum *species)*, Permanent Agriculture Resources, Holualoa, Hawai'I, USA.

Thomson LAJ, Doran JC and Baskorowati L (2018d) '*Swietenia macrophylla*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 214–216.

Thomson LAJ and Evans B (2006) '*Canarium indicum* var. *indicum* and *C. harveyi* (canarium nut)', in Elevitch CR (ed) *Traditional trees of Pacific islands: their culture, environment and use*, Permanent Agriculture Resources, Holualoa, Hawai'I, USA, ISBN 0-9702544-5-8, p. 209–226.

—— (2018) '*Terminalia* catappa', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 224–227.

Thomson LAJ and Gâteblé G (2020) 'Casuarinaceae genetic resources in the Pacific Islands: enhancing their contributions to the green economy', in Haruthaithanasan M, Pinyopusarerk K, Nicodemus A, Bush D and Thomson L (eds) *Proceedings of the sixth international Casuarina workshop: casuarinas for green economy and environmental sustainability, Casuarina 2019*, Krabi, Thailand 21–25 October 2019, p. 31–42.

Thomson LAJ, Pouli MAT and Alatimu ST (2018e) '*Terminalia richii*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, p. 228–231.

Thomson LAJ, Rimbawanto A and Doran JC (2018f) '*Santalum album*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 196–199.

Thomson LAJ and Sam C (2018) '*Barringtonia edulis*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 65–68.

Thomson LAJ and Thaman RR (2006) '*Alphitonia zizyphoides* (toi)', in Elevitch CR (ed) *Traditional trees of Pacific islands: their culture, environment and use*, Permanent Agriculture Resources, Holualoa, Hawaii, USA, ISBN 0-9702544-5-8, p. 57–68.

—— (2018) '*Pometia pinnata*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 188–191.

Thomson LAJ, Thaman RR, Guarino L, Taylor M and Elevitch C (2018g) '*Pandanus tectorius*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 179–183.

Thomson LAJ, Thaman RR, Martel F and Elevitch CR (2018h) '*Intsia bijuga*', in Thomson L, Doran J and Clarke B (eds), *Trees for life in Oceania: Conservation and utilisation of genetic diversity*, ACIAR Monograph No. 201, Australian Centre for International Research, Canberra, Australia, p. 143–146.

Turnbull JW (2002) 'Tree domestication and the history of plantations', in Squires VR (ed) *The role of food, agriculture, forestry and fisheries and the use of natural resources*, Encyclopedia of Life Support Systems developed under auspices of UNESCO, Eolss Publishers, Oxford, UK, p. 48–74.

Underhill SJR, Stringer R, Bryceson K, Prasad BC and Shearer D (2011) 'The Pacific Agribusiness Research for Development Initiative (PARDI): a novel approach to horticultural development in the Pacific', in Kahane R, Martín Martín LM and Martín A (eds) *XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on Horticulture for Development*, Lisbon, Portugal, 22–28 August 2010, International Society for Horticultural Science, Leuven, Belgium, p. 17–24.

Uwamariya A (2004) '*Dracontomelon dao* (Blanco) Merr. and Rolfe', in Gunn B, Agiwa A, Bosimbi D, Brammall B, Jarua L and Uwamariya A (eds) *Seed handling and propagation of Papua New Guinea's tree species and forest products*,: CSIRO Forestry and Forest Products, Canberra, p. 38–39.

Verheij EWM (1991) '*Spondias cytherea*', in Verheij EWM and Coronel RE (eds) *Plant resources of South-East Asia No. 2: edible fruits and nuts*, PUDOC, Wageningen, Netherlands, p. 287–288.

Viji I, Sethy M, Smith A and Thomson L (2000) *Report on field trials established in 1998 and 1999 at Shark Bay Field Research Station, Santo, Vanuatu*, Vanuatu Department of Forests, Luganville, Vanuatu, and South Pacific Regional Initiative on Forest Genetic Resources (SPRIG).

Viranamangga R (2013) Endospermum medullosum *(whitewood) value chain analysis and opportunities for value-adding in Vanuatu*, master's thesis, Southern Cross University, Lismore, NSW, Australia.

Viranamangga R, Palmer G and Glencross K (2012) 'Plantation-grown whitewood timber in Vanuatu: challenges and opportunities for export and domestic use', *International Forestry Review*, 14:486–491.

VNSO (Vanuatu National Statistics Office) (2021) *Labour Market Monograph 2019–2020 NSDP Baseline Survey*, VNSO.

Vutilolo IVN, Tyagi AP, Thomson LAJ and Heads M (2005) 'Comparison of performance of whitewood (*Endospermum medullosum* L. S. Smith) provenances and families in Vanuatu', *The South Pacific Journal of Natural Science*, 23:37–42.

Walker S (2015) *Development and delivery of germplasm for sandalwood and whitewood in Vanuatu and northern Australia*, Review report for ACIAR Project: FST/2008/010, Australian Centre for International Agricultural Research, Canberra, Australia.

Wallace H, Johns C, Carter J, Jones K, Randall B, Raciti M, Bunt C, Grant E, Walton D, Nevenimo T, Tungon J, Viji I, McKenzie V and Pauku R (2016) *Developing markets and products for the Pacific Island and PNG canarium nut industry*, Final report for ACIAR Project FST/2010/013, Final Report Number: FR2016–33, Australian Centre for International Agricultural Research. Canberra, Australia.

Wallace H, Komolong B, Nevenimo T, Waaii C, Hannett D, Hannett G, Ling SK, Grant E, Hodges B, Kill E, Randall B, Jennifer Carter, Ashford G, Bai SH, Johns C, Simos T and Jones K (2021) *Enhancing private sector-led development of the Canarium industry in PNG*, Final report for ACIAR project FST/2014/099, Final report number: FR2021–022, ACIAR, Canberra, Australia.

Walter A and Lebot V (2007) *Gardens of Oceania* (Ferrar P trans), ACIAR Monograph. No. 122, Australian Centre for International Agricultural Research, Canberra, Australia.

Walter A and Sam C (1993) *A variety collection of nut trees and fruit trees in Vanuatu*, Institut Francais de Recherche Scientifique Pour le Developpement en Cooperation, Port Vila, Vanuatu.

—— (2002) *Fruits of Oceania*, ACIAR Monograph No 85, Australian Centre for International Agricultural Research, Canberra, Australia.

Walters P and Lyons K (2016) 'Community teak forestry in Solomon Islands as donor development: when science meets culture', *Land Use Policy*, 57:730–738.

Warman RD (2014) 'Global wood production from natural forests has peaked', *Biodiversity and Conservation*, 23:1063–1078.

Weiss E (2015) '"Beginnings of Fruit Growing in the Old World" – two generations later', *Israel Journal of Plant Sciences*, 62:75–85.

White TL (1987) 'A conceptual framework for tree improvement programs', *New Forests*, 1:325–342.

White TL, Adams WT and, Neale DB (2007) *Forest genetics*, CABI Publishing, Wallingford, UK.

Wilkie ML, Eckelmann C, Laverdiere M and Mathias A (2002) 'Forests and forestry in small island developing states', *International Forestry Review*, 4:257–267.

Yen DE (1993) 'The origins of subsistence agriculture in Oceania and the potentials for future tropical food crops', *Economic Botany*, 47:3–14.

—— (1996) 'Melanesian arboriculture: historical perspectives with emphasis on the genus *Canarium*', in Stevens ML, Bourke RM and Evans BR (eds) *South Pacific indigenous nuts: proceedings of a workshop 31 October – 4 November 1994, Le Lagon Resort, Port Vila, Vanuatu*, Australian Centre for International Agricultural Research, Canberra, Australia, p. 36–44.

Zobel B and Talbert J (1984) *Applied forest tree improvement*, Wiley and Sons, New York.

Zohary D (2004) 'Unconscious selection and the evolution of domesticated plants', *Economic Botany*, 58:5–10.

Chapter 3

Recognising different interests among local stakeholders: case studies from the Philippines and Papua New Guinea

Kanchana Wiset, Nathan Wampe, Roger Tripoli and Robert Fisher

Abstract

Addressing the interests of local people is essential for successful smallholder forestry and forest landscape restoration (FLR). Clarifying their interests and needs is a key aspect of the implementation principles of FLR. However, seeking a detailed understanding of local interests is often forgotten or understated in the design, planning and implementation of reforestation projects.

We used interviews and landscape visualisation techniques to identify the interests of local people involved in FLR and smallholder forestry in the Philippines and Papua New Guinea (PNG). The study aimed to explore what kind of landscapes local people want to see in the future and why they prioritise those landscape scenarios. We also investigated details of local context and socioeconomic conditions that influence local interests. Our findings revealed that local people in both case studies were interested in reforestation interventions that can support and generate multiple benefits for their household consumption and food security. The background to their interests related to the species to grow, the planting patterns and the scale of planting. In both cases, local people did not visualise growing large numbers of timber trees as the dominant planted products for restoring the degraded landscapes. They preferred degraded lands to be restored with mixed planting of various species through small-scale activities. Men and women had different preferences for species selection and planting locations.

Our study highlights that to recognise local interests, FLR implementers need to know more than what local people want to plant. It is essential to understand how local people see the relationship between their livelihoods and the landscapes within which they live. The study highlighted that pre-identification of interventions should not be done by external experts. The implementers need to engage local people effectively to design, negotiate and make decisions about restoring their own landscapes.

Acknowledgement

We wish to acknowledge the participation of all informants in the case study sites – Leyte and Biliran provinces of the Eastern Visayas region of the Philippines, and the Ramu–Markham Valley of Papua New Guinea. Our fieldwork benefited from the great support of staff from our projects' local partner organisations in both countries. We also thank the team from Visayas State University (Maria Ofelia Moreno, Katty Escribano Rife, Arturo Pasa, Crisanto Solano, Kenneth Bryan Doria, Jhan Rey Leysa, Nova Santa Parcia, and others) and the team from Ramu Agri-Industries Ltd (Melinda Thom, Clifford Single, Zephaniah Waviki, William Unsworth and Laszlo Mathesl, and other support staff from the Sustainability Unit).

Introduction

While many restoration and reforestation programs have applied the concept of FLR, many have reported challenges, particularly because the programs did not work effectively to enhance local livelihoods. Commonly, the failures were caused by top-down implementation limiting local participation (Djenontin et al. 2018), resulting in local interests being overlooked (Coppus et al. 2019). Frequently, the restoration options were determined by external experts (Boedhihartono and Sayer 2012), ignoring local preferences for species selection (Meli et al. 2014). Top-down implementation often led to plantation targets being pre-set and local people being involved only in planting activities for landscape restoration rather than in making decisions about options for intervention.

FLR has been widely promoted as a global approach to forest restoration. The concept emerged in the year 2000 through an expert workshop – organised by the International Union for Conservation of Nature and the World Wide Fund for Nature – to address the concerns of previous conventional forest restoration initiatives (Mansourian 2005). FLR was proposed to achieve the dual initiatives of restoring land and resources for ecological benefits and livelihood improvement (Maginnis and Jackson 2007). The concept is underlined by landscape approaches, which are ways to plan and manage landscapes to balance the uses of resources for different objectives such as for ecological, social and economic purposes (Sayer et al. 2013).

In this chapter we discuss the need to address the interests of local people in the implementation of landscape restoration initiatives, including FLR and smallholder forestry. We present potential approaches and suggest a method for investigating the interests of local people. We focus on research carried out by the first author as part of her PhD research (Wiset 2022). The research was carried out in the context of 2 projects funded by ACIAR and implemented by the University of the Sunshine Coast in partnership with Visayas State University in Leyte Province in the Philippines and with Ramu Agri-Industries Ltd in the Ramu–Markham Valley in PNG.

Landscape stakeholders and interests

Typically, every landscape has many stakeholders who depend on and are involved in the utilisation and management of resources in a variety of ways. In this context, stakeholders are people affected directly or indirectly, positively or negatively, by a decision or action on landscape management (Higman et al. 2005); they can also be active or passive (Grimble and Wellard 1997). In this chapter, we define landscape stakeholders based on these definitions, broadly categorising them as either a) people and groups who affect the implementation of landscape restoration or b) people and groups who are affected by the implementation of landscape restoration. A landscape stakeholder can be an individual or a group, and they can fit into either (or sometimes both) of the 2 broad categories.

Different stakeholders have different interests. Freeman (2010) explained, in the context of business management, that different stakeholders have multifaceted stakes and interests and that trade-offs of these diverse interests are required to engage them well in a working process. In the context of forest restoration, stakeholders hold different perceptions, beliefs and objectives about the use and management of resources within landscapes (Sayer et al. 2013). Their different roles and interests influence their engagement in the process and implementation of FLR (Lazos-Chavero et al. 2016). It is important that their diverse motivations about social and ecological aspects are simultaneously recognised for identifying restoration goals and for providing different incentives based on their diverse interests (Jellinek et al. 2019).

Stakeholders will engage in landscape-level initiatives if restoration options respond to their interests (Sayer et al. 2013) or valuable reasons and benefits motivate them to do so (Sayer et al. 2015). Recognising the different interests of relevant stakeholders is essential for planning and implementing landscape restoration initiatives. Addressing the interests of local people is particularly important – given their livelihoods depend on resources within their landscape, they are key landscape stakeholders.

Local people and their engagement in forest restoration

Higman et al. (2005) identified local stakeholders, who are forest dependent, into several groups:

- Ethnic and Indigenous groups who have lived in forests for many years and depend on the forest and its resources for their daily living. They have good traditional knowledge and resource management practices.
- Rural people who live near forests, including settlers from other areas. They come to collect forest products and fuelwood, and to use forest areas for grazing and cultivation.
- Small-scale entrepreneurs engaged in small-scale commercial forestry, processing forest products for the markets, such as through logging.
- Forest workers, including rural people, who seek wages and other direct benefits from forest resources and management, working in the formal sector (for example, working in plantations and nurseries) or the informal sector (for example, collecting firewood).

In the context of this study, 'local people' refers to rural people who live in or adjacent to forests, and whose living depends on benefits from forests in various ways.

Participation of local people is recognised by various sets of guiding principles for implementing forest and landscape restoration.[4] Approaches and initiatives for landscape restoration need to be tailored to local contexts (Besseau et al. 2018) and aimed at improving the livelihoods of local people in economic and non-economic aspects (such as human capital) (César et al. 2020). Recently, the United Nations Decade on Ecosystem Restoration 2021–2030 was launched, and one of the 10 principles emphasises the importance of engaging local people. This principle advises that landscape restoration initiatives be tailored to local ecological, cultural and socioeconomic conditions (UNEP and FAO 2021). Restoration initiatives should recognise local knowledge, strengthen the participation of affected locals and ensure the provision of fair benefits (Osborne et al. 2021).

When local people are effectively engaged, restoration initiatives are likely to be implemented well and achieve success; local people, after all, have a direct stake in the landscape resources undergoing restoration (Djenontin et al. 2018). Ideally, local people may be categorised by the 2 landscape stakeholder types – either those who gain or those who lose from landscape restoration (Mansourian 2018).

Many studies have identified the positive benefits that local people can gain from being involved in restoration projects. Positive benefits include improvements in socioeconomic opportunities (Sacande et al. 2021), such as income generation from plantation activities (Adams et al. 2016; Li et al. 2017) and payments and subsidies from restoration programs (Adams et al. 2016).

4 See, for example, Besseau, Graham and Christophersen (2018), César et al. (2020), Osborne et al. (2021) and Sayer et al. (2013).

In contrast, some FLR programs have had negative impacts on local people and failed to provide full benefits for local communities, particularly where the restoration programs were developed by experts and technical agencies (Boedhihartono and Sayer 2012). Projects that were blinded by top-down implementation, limiting the participation of local stakeholders, tended to be weak, leading to failed outcomes (Djenontin et al. 2018). Coppus et al. (2019) found that many top-down restoration projects overlooked local people in the planning phase; in particular, local preferences for species selection were often ignored (Meli et al. 2014).

Restoration initiatives need to support collaboration among local people in deciding what they want and how restoration activities can occur within their communities and landscapes (Elias et al. 2021). While many restoration programs include local people, the ways of planning and recognising their interests may be inappropriate.

Our research in the Philippines and PNG

Our research explored how the interests and needs of different stakeholders varied according to gender and livelihood conditions in the Eastern Visayas region of the Philippines and the Ramu–Markham Valley (RMV) of PNG. These case studies are examples of different policy and socioeconomic contexts, which, in common, illustrate challenges in identifying stakeholder interests and methods for examining those interests. The case studies were undertaken by the University of the Sunshine Coast (UniSC) in partnership with Visayas State University in the Philippines and Ramu Agri-Industries Ltd (RAIL) in PNG. The selected case study locations have different tenure systems, which affect local people's access to and uses of land and forest resources and their experiences with restoration and reforestation projects.

Research methods

Interviews and visualisation were the key methods we applied in this research. Participant observation was also conducted and contributed to the understanding of local context.

Interviews

In Eastern Visayas, individual interviews were conducted with the members and officials of 4 people's organisations (POs), exploring their experiences and motivations for joining in the reforestation projects and their future reforestation scenarios. Group interviews were conducted with each PO to explore members' involvement and the challenges they faced when participating in reforestation projects implemented by different agencies.

In the RMV, the individual interviews with clan leaders and male and female informants aimed to explore the uses of land, including decisions about planting more trees in the family gardens. Several group interviews were also conducted:

- A group interview with clan leaders and elders was aimed at gaining a better understanding of the uses of clan lands and the decisions about planting trees on clan land.
- A women's group interview aimed to identify any specific gendered interests and the roles and involvement of women in decisions about tree planting.
- A group interview with the mixed group of families involved in the pilot activities of the ACIAR project sought their opinions about integrating suitable tree planting approaches in their current gardens.

Case study: Eastern Visayas, the Philippines

Land resources in the Philippines are categorised as alienable and disposable lands, protected areas (national parks), forestlands and mineral lands (Guiang et al. 2012). Our research, carried out in 2 provinces in Eastern Visayas, examines reforestation of forestlands and the provinces' engagement of local people in implementation. These forestlands are frequently degraded. Local people are not legally permitted to live in forestlands or use forest products. They live near or around the boundaries of forestlands. The research partner was the Visayas State University (VSU). Since 2016, UniSC and VSU have been researching how restoration could improve local livelihoods.

In the Philippines, the Department of Environment and Natural Resources (DENR) is the government agency responsible for managing the forestlands. In 1995, DENR consolidated all people-based forest management programs under the umbrella of the Community-Based Forest Management program, which was implemented as a national strategy to promote sustainable forestry and social justice (Pulhin et al. 2008). In the 2000s, one of the many national restoration programs developed to address deforestation and forest degradation was the National Greening Program,[5] which utilised forest landscape restoration as its implementation approach (DENR 2016).

The Eastern Visayas case study focused on 4 sites in the provinces of Leyte and Biliran involving 4 people's organisations (POs). Three of the 4 POs were target sites for the ACIAR project. Two of the POs were in Leyte Province, one each in Capoocan and Kananga municipalities, and another PO was in Biliran Province in Caibiran Municipality. Two POs had already participated in National Greening Program projects (implemented by DENR) and in other projects implemented by non-government organisations:

- Established in 1989, the PO in Capoocan was granted a community-based forest management agreement[6] for using and managing 577 ha of forestlands.
- The PO in Caibiran was set up in 2011 under a subgroup of a large-scale PO – the Community Forestry Program Beneficiaries Association – and was granted a community-based forest management agreement to manage 4,886 ha of forestlands.

The PO in Kananga, which was set up in 2011, did not participate in National Greening Program projects and did not hold a community-based forest management agreement at the time of our research, but was involved with the private sector in implementing the reforestation projects in the forestlands.

The fourth PO, based in Albuera Municipality in Leyte, was not one of our project's target communities. However, it was recognised as an outstanding PO by DENR, who selected it to implement National Greening Program projects. Consequently, we saw it as a potentially interesting case study. Established in 2014, this PO does not hold a community-based forest management agreement.

All of the group members in the 4 selected POs applied traditional farming practices in the form of swidden agriculture.

5 The National Greening Program of the Philippines is a national effort to restore degraded and denuded forest landscapes. It was originally targeted to plant 1.5 billion trees covering 1.5 million ha from 2011 to 2016. This was extended in 2016 to rehabilitate a further 7.21 million ha by 2028 (GoP 2015). The program aims to enhance the development of forest plantations with greater participation from the private sector, local government, and POs (DENR 2019).

6 Community-based forest management agreements are granted to participating communities (that is, people's organisations) for a period of 25 years, and are renewable for another 25 years. This instrument allows communities to participate in management and conservation of forestlands and natural resources within a designated area.

Case study: Ramu–Markham Valley, Papua New Guinea

The Ramu–Markham Valley (RMV) of PNG was the research site for ACIAR research projects implemented by UniSC in partnership with Ramu Agri-Industries Ltd (RAIL). RAIL operates commercial agricultural production of oil palm, sugar and beef in large parts of the central area of the RMV. To meet its goals for sustainability and corporate social responsibility, RAIL promotes tree planting for enhancing livelihoods of their partner communities. Since 2013, UniSC and RAIL have implemented tree planting projects for the RMV farmers, aimed at restoring forests and improving livelihoods.

Almost all (97%) of the land in PNG is held under customary land ownership, which was recognised by the PNG constitution in 1975 (Blaser et al. 2011). This tenure system gives customary landowners rights to access, use, manage and inherit land and natural resources (Holzknecht 2017). Customary landowners are clans, which govern and allocate the rights to their members to use land for cultivation and ensure secure tenure for the next generation. Although customary lands have been traditionally used for semi-subsistence living, the villagers have rights to grow crops for sale for their household income.

Located in the north of PNG, the RMV actually comprises 2 valleys, the Ramu and the Markham, through which rivers flow in different directions, although it is essentially one major valley with separate but closely related watersheds. The valley is surrounded by mountain ranges, the coastal Finisterre and Saruwaged ranges, as well as the main highland range. Most of the valley floor is covered with anthropogenic grasslands, with some forest found on the high slopes of surrounding hills and mountains. The study area is in 2 districts, one from each of 2 provinces: the Markham district of Morobe Province and the Usino Bundi district of Madang Province. The selected research sites for this study were in 3 villages in the central grassland portion of the valley. In each case, we worked with members of one clan and its involvement in land-use planning on its clan land.[7]

The villagers were mainly gardeners, using the traditional practice of swidden agriculture. In addition, parts of the study area were used for large-scale commercial agriculture, such as sugarcane and oil palm plantations, rice fields and cattle stations. These operations are run by large companies that have leased land from clans or from the government. As the forest cover on mountain slopes is not easily accessible, the RMV is not a priority area for the forest industry.

Visualisation

Visualisation was a key technique applied in the research and what follows aims to describe its uses in understanding local people's needs.

'Visualization is any technique for creating images, drawings, or animations to communicate a message or idea […] ' (Boedhihartono 2012:13). Landscape visualisation can be implemented through drawing or mapping methods. These methods are referred to by different names by various authors, including visioning maps (Evans et al. 2006), visualisation technique (Boedhihartono 2012), participatory mapping (Cadag and Gaillard 2012) and participatory art (Johansson and Isgren 2017).

7 In the RMV, multiple clans may live in a single village and clan members may live in multiple villages. Clan lands tend to be scattered rather than being in a single contiguous territory.

In our research, visualisation techniques were used so that local people could convey what land-use options they preferred for restoration in their landscapes. Visualisation is useful for identifying what trees should be planted, but it can also engage local people effectively in deciding what land uses within a landscape would look like and which plantation activities would most benefit their livelihoods.

Visualisation exercises were used with male and female farmers living in the study sites. The exercises produced the visual data for understanding the interests of local people in restoration activities and the factors influencing their interests.

The steps in the application of visualisation were adapted from Boedhihartono's (2012) guidelines:

1. The participants were informed of the purpose of the exercise.
2. They were divided into small groups of 5–10 persons and given flipcharts and coloured pens.
3. The groups were encouraged to discuss their preferences for reforestation and restoration in the landscape in which they lived and to draw their desired scenarios of future land uses (in the next 5 to 10 years). They were also asked to provide brief descriptions and reasons as to why they drew these scenarios.
4. The participants presented their drawings and their descriptions to other groups.

These broad steps were implemented in both case studies, although with some differences in detail.

For the Eastern Visayas case, the participants had experiences working for many reforestation projects as community-based action (that is, as members of a PO), but, with the exception of the PO in Caibiran, they had not been involved in designing the land-use options for reforestation. Our visualisation exercises asked the POs what scenarios they would prefer to implement, if given the opportunity to design reforestation options.

For the RMV case, the visualisation exercises were designed differently. Clans own the land and access rights, and make decisions about the use and management of their land. For instance, clans make decisions about large-scale tree planting initiatives to be implemented on their land. The individual clan members and their families hold the rights to use their allocated land for their livelihoods. Men and women are involved in different ways in making land-use decisions about gardening and their family's crop management. Two different drawing exercises allowed them to consider either the landscape scale (for example, over clan land) or the family-garden scale. For the landscape-scale drawing exercises, the male and female participants worked separately in small groups to discuss and draw scenarios for growing more trees in their landscape. For the drawings at the family-garden scale, the male and female participants were individually asked to draw the farming patterns illustrating the tree planting that they would like to implement in their family gardens.

Participant observation

Participant observation was used to provide context for the study. It took place during the implementation of research activities in the field, seeking to learn about livelihood activities and social interactions.

Results of the Philippines case study

Local people in Eastern Visayas did not want timber trees to cover all of the degraded areas on the mountain slopes. They preferred planting various tree species in different zones of the mountain areas (Figure 3-1). For instance, on mountain peaks they wanted to plant more timber trees, particularly native tree species, to prevent landslides and control flooding. Those trees could also provide materials for fuelwood and housing.

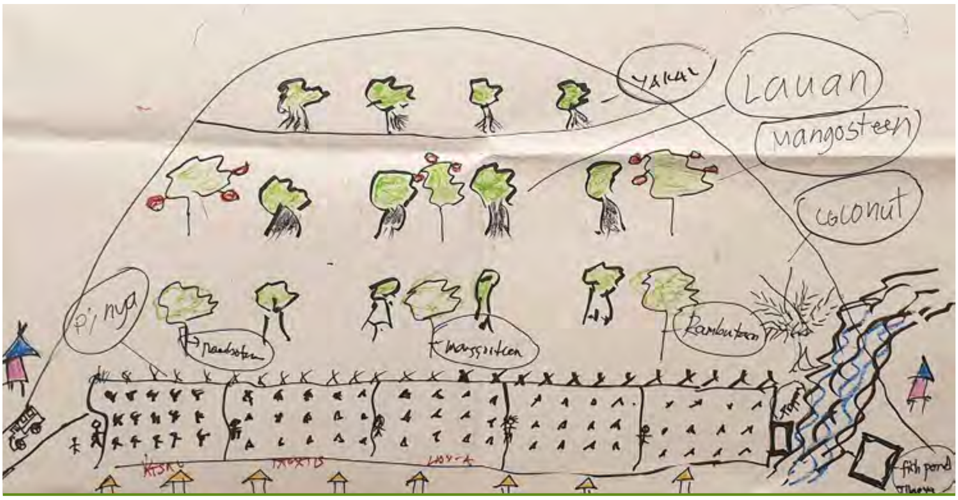

Figure 3-1: **This drawing illustrates a zoning system for growing mixed species. It was drawn by a group of male members from one of the POs in Leyte Province.**

In terms of species preferences, participants preferred mixing timber trees with fruit trees and root crops to ensure food security and family income (Figure 3-2). They preferred timber trees to be grown at a farm scale and to fit with current farming practices.

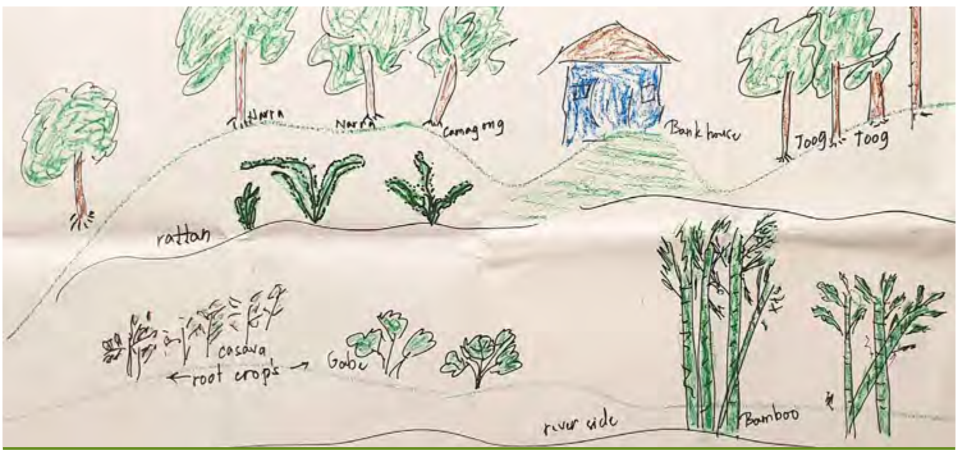

Figure 3-2: **This drawing by a mixed group of males and females in Leyte Province shows a preference for planting mixed species in the landscape (see Figure 3-3 and Figure 3-4).**

Figure 3-3: **The landscape of the case study sites in Eastern Visayas. The mixed-species planting refers to the existing land uses applied by PO members. (Top) A garden in Capoocan Municipality; (Bottom) Farmlands (rice paddy field and mixed fruit trees) at the foothill and timber trees planted on the high slope in Kananga Municipality**

Figure 3-4: **The landscape of the case study sites in Eastern Visayas. The mixed-species planting refers to the existing land uses applied by PO members. (Top) A mixed-species garden along the stream running down from the mountain in Albuera Municipality; (Bottom) A landscape in Caibiran Municipality.**

Men wanted mainly timber trees when reforesting high slopes of mountains. Women wanted reforestation to focus on benefits for households. Most women participants wanted fruit trees and agricultural crops, rather than timber trees, within the plantation sites. Figure 3-5 shows these differences.

Figure 3-5: (Left) A drawing by a group of male PO members in Eastern Visayas shows their interest in growing timber trees as the dominant species. (Right) A drawing by female members of a PO in Leyte Province shows that growing fruit trees and root crops is their main priority for reforestation.

Figure 3-6: The visualisation exercises underway with female (left) and male (right) PO members.

The desired landscape as expressed by the participants in the visualisation exercises was different from the landscape that resulted from the reforestation projects, particularly the National Greening Program projects implemented by government agencies. The PO leaders and members saw reforestation on the mountains as a way of mitigating the impacts of natural disaster. However, the main reason local people participated in these reforestation projects was the wage income provided, not the long-term benefits of tree plantations (Wiset 2022). The underlying problems were a lack of inclusion of local people's interests and decisions in land-use planning for reforestation and poor devolution of power to local people during implementation of reforestation projects (Wiset et al. 2023). Local people were not involved in deciding what species would be planted and how they could use the land following reforestation. It would seem that where reforestation projects are not tailored to local contexts in terms of tree species selection and placement, what local people want differs markedly from what projects think they want.

Results of the PNG case study

Forests are found on the peaks and high slopes of hills and mountains in the RMV, not on the valley floors. As a result of this inaccessibility, villagers said it was difficult to find good timber for housing and they wanted to increase the number of trees in the grasslands. They were particularly interested in planting more timber trees to provide household benefits (such as fuelwood and material for housing) and for crop management (shading to increase cash crop productivity). Fruit trees were desired for daily food consumption and for selling any surplus to supplement income.

Although they recognised the benefits of increasing tree resources in their grasslands, they did not want trees planted across their clan lands (Figure 3-7). They preferred small-scale tree planting in order to preserve their lands for use by the next generation and to keep the kunai grass for traditional hunting.

Figure 3-7: A drawing by a group of women in the RMV showing their preference for planting more timber trees and fruit trees near home gardens, leaving some areas for kunai grass and preserving land for future use.

The RMV villagers preferred planting mixed tree species in different gardens, benefiting different functions and purposes (Figure 3-8). For instance, they preferred both timber and fruit trees to be mixed with food crops in home gardens for household consumption.

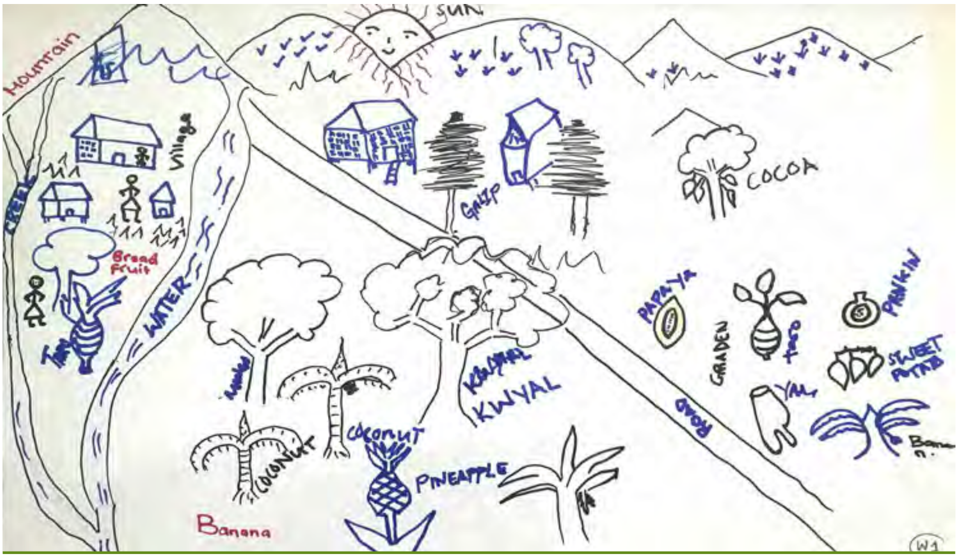

Figure 3-8: **A drawing by a group of women in the RMV shows their preference for planting mixed species.**

Figure 3-9: **Grassland landscape of the study site in the RMV (left) and mixed species planted in a home garden (right)**

Figure 3-10: **A garden for growing coffee mixed with timber trees on the mountain foothill (left) and a staple crop garden grown on the plain grassland area in the RMV (right)**

Figure 3-11: Visualisation exercises were conducted separately with male villagers (left) and female villagers (right)

Men prioritised the planting of timber trees in their cash crop gardens. Women focused on the benefits for daily food production, so they wanted mixed species planted in the gardens that they managed (Figure 3-12). However, they did not want trees to be planted with their staple crops (such as yam and sweetpotato) as they perceived that trees could block the sunlight and this would affect crop production.

Figure 3-12: (Left) A drawing by a male farmer in the RMV indicates his preference for growing timber trees as the dominant species in his garden and (right) a drawing by a female farmer shows her preference for growing fruit trees and food crops as the main priority in her garden.

Customary land tenure governs land-use decisions, in terms of who can make decisions at what level. Under the tenure system, families in the RMV can make decisions about land use, including tree planting, in their allocated family plots. However, decisions about planting trees on a large scale must involve the clans (Wiset et al. 2022).

Outcomes of the research: has it led to change?

It is important here to make some comments about the practical impacts of the visualisation process on the local people and on the reforestation process and practices.

We cannot claim that the process led to major substantive changes in the immediate time frame.[8] Rather than asking about immediate benefits to the local people, the most meaningful question is more about whether the process helped us to understand people's needs better and whether it helped us to avoid mistakes, such as failing to understand the perspectives of women.

In the case of the Philippines, we improved our understanding of what people wanted from reforestation activities under the National Greening Program. It became clear that the program did not address local needs from reforestation because it did not allow for any use of the restored forests by community members. The benefits of participation to livelihoods were mostly from the payments made to the POs for their labour rather than from sustained use. The primary constraint in addressing local needs rests in the policy framework, which sees forestlands as a land category legally defined as being under state control and which does not allow local people to use forest products or carry out agriculture within forestlands.

The potential for change in the Philippines rests in the potential for the research to influence policy, and that was beyond the immediate scope of the research. We hope that the published results of the research, and the experience and influence of project partners, may influence the policy in the longer term.

In the case of the RMV, the research was undertaken with the active involvement of staff from RAIL, our project partner. (One RAIL staff member is also a co-author of this chapter.)

The research in the RMV did inform reforestation activities, by providing a much clearer idea of what people wanted from reforestation in terms of their livelihoods. A major project improvement came from a better understanding of the specific interests of women in the outcomes of project activities. The research clearly gave women much better access to communicate their needs. The co-author from RAIL, Nathan Wampe, has confirmed that the lessons from the research have continued to inform RAIL reforestation activities with communities after the project has ended.

8 The COVID-19 pandemic has severely limited field activities since early 2020, and this has been a factor in limiting tangible outcomes since the research was completed.

Discussion

Many publications highlight how it is essential to ensure restoration and reforestation initiatives are tailored to respond to local people's needs and interests. This research describes an approach that can contribute to achieving this goal. This discussion focuses on the key lessons from the methodology applied in the 2 case studies for identifying the interests of local people in reforestation and agroforestry. Using a mix of visualisation, interviews and participant observation achieved the following benefits for investigating local people's interests and understanding them in depth.

Understanding local peoples' interests in tree planting

In both case studies, local people saw the importance of having both timber trees and fruit trees in their landscapes. Their drawings showed that they recognised the benefits and services that trees and forests provide to their livelihoods. The drawings revealed where local people wanted landscapes to be restored and for what purposes, and where they did not want it. Local people preferred trees to blend with their cultivation – in essence, they preferred agroforestry, where trees are grown as part of people's existing land use.

Monoculture timber tree plantations were not preferred in either case study. Local people wanted tree planting to be mixed with other crops, which can provide multiple benefits to their livelihoods. Local people did not expect commercial benefits from growing trees as a single source of income generation or as a crucial driver for their engagement in restoration. Consequently, the findings confirmed that a monoculture timber tree plantation at large scale was neither suitable nor a preferable approach for the local people in the 2 case studies. Many restoration projects, however, implement large-scale monoculture timber tree plantations to quickly establish trees and restore degraded landscapes.

Visualising their landscape in the future

Both case studies identified local people's interest in the scale of operation and the location for tree planting, the planting approaches and the species preferences. Local people did not visualise tree planting in large-scale reforestation across landscapes; rather, they preferred trees to be planted in different areas for different purposes. In both case studies, local people wanted mixed species for restoration options and their preferred approaches were identified as small-scale tree planting and mixed-species planting. Agricultural activities formed the main source of income for local people and they supported initiatives and approaches that were consistent with their farming practices, including ensuring their subsistence living and income generation for their families.

Being gender responsive

Our research findings revealed that men and women living in the study sites had different roles in farming activities, which influenced their different interests in tree planting. The findings also showed that the detailed preferences of men and women for restoration activities were linked to the benefits based on division of labour according to gender. These differing preferences related to the preferred location, pattern and species for tree planting. However, there was one similar finding across gender – both male and female participants shared a preference for mixing timber trees, fruit trees and food crops as a restoration option. Clearly, the process for designing land-use needs to be based on gender preferences. Different perspectives of restoration activities by gender are required in the design of restoration interventions (Djenontin et al. 2020).

Understanding gender is not only about knowing how women and men are involved in restoration activities, such as whether men will do heavier work and women will do lighter work in plantation activities. Rather, gender needs to move beyond gender-specific activities, such as by understanding who has power at which level to decide what to grow and which practices can be adopted in restoring plots of land (Tiendrébéogo et al. 2020).

The research results identified the involvement of men and women in land-use decisions. While there was not a significant difference between women and men in the case of Eastern Visayas, a greater difference was noted in the RMV. Women in the RMV were strongly involved in land-use decisions at family level, although the patrilineal system of land ownership and use rights practised in the area limited their involvement in decision-making at the clan level. Understanding gender issues in land-use decision-making needs to focus on who can make what decisions and who can implement these decisions.

Many restoration projects fail to consider gender interests. Catacutan and Villamor (2016) emphasised that, if restoration programs overlook gender-specific needs, particularly the interests of women, this may lead to implementation failure as those excluded lose interest in managing the trees after planting. They also highlighted that seeking to understand gender-specific differences about land-use practices and decisions is an entry point for landscape restoration. Therefore, restoration programs that miss out on the gender interests might not provide a balance of livelihood benefits for both men and women.

Using visualisation as an approach for enhancing the engagement of local people in land-use planning

Using visualisation exercises and interviews provided other means for local people to communicate their preferred and possible future landscapes for the benefit of their livelihoods and the environment. This is particularly relevant to the communication opportunities provided to women.

Visualisation exercises can enable people to develop shared ideas for landscape land-use planning and restoration. In this research, the exercises were implemented separately for men and women, as we sought to identify their preferences as 2 distinct groups of stakeholders. The exercises gave male and female participants the chance to draw their own visions for land use at a landscape scale and farm scale. The results of these exercises revealed that men and women have slightly different views and nuanced preferences about the uses of their landscapes in the future. The visualisation exercises were also used with the individual farmers (in the RMV case), with the findings showing that neither all men nor women hold the same visions. Drilling down to the details is needed for effective planning and implementation of restoration activities.

Being flexible in the design to respond to local context

Using a mix of methods gave the research team flexibility to set the scope and design of activities for learning from each country case study. For instance, we designed the focus and details of the visualisation exercises and interviews based on the local context and conditions, the rights over the land and resources, and the landscape restoration situation of each case study. This flexibility allowed the research to obtain information specific to each case study. Restoration options cannot be generalised, and one approach does not fit all. While the same methods can be applied in any specific case, the process and focus of investigation needs to be modified, taking into account the context and background conditions of each case.

Conclusion

It is commonly recognised that addressing local interests is essential before implementing any environmental or forestry project, and it is also recognised that this step is often (even usually) inadequately implemented. Our 2 case studies demonstrate how to gain a more nuanced understanding of local people's interests using visualisation techniques, in combination with interviews and participant observation.

The lessons learned include that the interests of local people are varied and specific, not only case by case, but are also specific to each actor and stakeholder group. Addressing local people's interests does not simply mean finding out what tree species they want to grow. Rather, it means helping them explore locations for restoration, which species they prefer to plant, and for what purposes. It also involves learning about the scale of operation they prefer and the land-use patterns they can adopt and adapt. In particular, the interests of local people are often specific to gender roles. The key insight of this research is that the realisation and detailed understanding of local people's needs and local conditions must first be addressed.

This research promotes a method for investigating in detail the interests of local people. In the process, this method also demonstrates ways for building and enhancing participatory processes and inclusive decision-making for planning and restoring land-use at the landscape scale. During the visualisation exercises, our participant groups interacted well and the process enabled discussion about negotiating and deciding together what they wanted, and what they did not want, as a result of landscape restoration. As well as generating visual data, the process can open opportunities for local people to identify and discuss with each other and with researchers the underlying reasons why they want, or do not want, to plant trees. Furthermore, this technique can create a platform for including and empowering minority and affected groups of people in land-use planning and decision-making (Johansson and Isgren 2017).

Most restoration and reforestation projects do not have detailed understanding of these points of view. Project managers often begin with their own assumption that planting more timber trees will be good for restoring lands, and the species are selected based on serving ecological improvement purposes as a priority. However, species selection, sites and scales of restoration might not fit and accommodate local people's livelihood benefits. These concerns can lead to failure because the project activities often do not serve local needs and cannot motivate local people to maintain restoration sites. Later, these sites may be converted to another land use by local people.

The method used in this research can be an alternative for project implementors and forestry practitioners who want to learn how local people want to realise their livelihoods in their landscapes, rather than predetermining land use from the top down.

Summary of insights / lessons

- Understanding local interests in reforestation programs does not need to be a difficult or expensive process.
- Visualisation (as described in this chapter) can be a relatively easy process for engaging local people in such a way that they can express their preferences.
- Men and women of the same community may not have the same preferences for tree planting and land use, and these differences can only be accommodated if they are expressed and understood at the project design stage, and changes of preferences are continually monitored.

References

Adams C, Rodrigues ST, Calmon M and Kumar C (2016) 'Impacts of large-scale forest restoration on socioeconomic status and local livelihoods: what we know and do not know', *Biotropica,* 48(6):731–744, doi:10.1111/btp.12385.

Besseau P, Graham S and Christophersen T (eds) (2018) *Restoring forests and landscapes: the key to a sustainable future*, Global Partnership on Forest and Landscape Restoration, Vienna, Austria, ISBN 978-3-902762-97-9.

Blaser J, Sarre A, Poore D and Johnson S (2011) *Status of tropical forest management 2011*, ITTO Technical Series No. 38, International Tropical Timber Organization, Yokohama, Japan.

Boedhihartono AK (2012) *Visualizing sustainable landscapes: understanding and negotiating conservation and development trade-offs using visual techniques,* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Boedhihartono AK and Sayer J (2012) 'Forest landscape restoration: restoring what and for whom?', in *Forest landscape restoration,* World Forests vol. 15:309–323, doi:10.1007/978-94-007-5326-6_16.

Cadag JRD and Gaillard J-C (2012) 'Integrating knowledge and actions in disaster risk reduction: the contribution of participatory mapping', *Area,* 44(1):100–109.

Catacutan DC and Villamor GB (2016) 'Chapter 6.2 – Gender roles and land use preferences –implications to landscape restoration in Southeast Asia', in Chabay I, Frick M and Helgeson J (eds) *Land restoration*, Academic Press, Boston, pp. 431–440.

César RG, Belei L, Badari CG, Viani RA, Gutierrez V, Chazdon RL, Brancalion PHS and Morsello CP (2020) 'Forest and landscape restoration: a review emphasizing principles, concepts, and practices', *Land,* 10(1):28.

Coppus R, Romijn J, Méndez-Toribio M, Murcia C, Thomas E, Guariguata MR, Herold M and Verchot L (2019) 'What is out there? A typology of land restoration projects in Latin America and the Caribbean', *Environmental Research Communications,* 1(4):041004.

DENR (2016) *DENR Administrative Order No. 2016-20: Implementing rules and regulations on Executive Order No. 193, Series of 2015: Expanding the coverage of the National Greening Program*, Department of Environment and Natural Resources, Republic of the Philippines.

——(2019) *DENR Administrative Order No. 2019-03: Revised implementing rules and regulations on Executive Order No. 193, Series of 2015*: Expanding and enhancing the coverage of the National Greening Program, Department of Environment and Natural Resources, Republic of the Philippines.

Djenontin INS, Foli S and Zulu LC (2018) 'Revisiting the factors shaping outcomes for forest and landscape restoration in Sub-Saharan Africa: a way forward for policy, practice and research', *Sustainability,* 10(4): 906.

Djenontin INS, Zulu LC and Ligmann-Zielinska A (2020) 'Improving representation of decision rules in LUCC-ABM: an example with an elicitation of farmers' decision making for landscape restoration in central Malawi', *Sustainability,* 12(13):5380.

Elias M, Kandel M, Mansourian S, Meinzen-Dick R, Crossland M, Joshi D, Kariuki J, Lee LC, McElwee P, Sen A, Sigman E, Singh R, Adamczyk EM, Addoah T, Agaba G, Alare RS, Anderson W, Arulingam I, Bellis SKV, Birner R, De Silva S, Dubois M, Duraisami M, Featherstone M, Gallant B, Hakhu A, Irvine R, Kiura E, Magaju C, McDougall C, McNeill GD, Nagendra H, Nghi TH, Okamoto DK, Valencia AMP, Pagella T, Pontier O, Post M, Saunders GW, Schreckenberg K, Shelar K, Sinclair F, Gautam RS, Spindel NB, Unnikrishnan H, Wilson GN and Winowiecki L (2021) 'Ten people-centered rules for socially sustainable ecosystem restoration', *Restoration Ecology*, 30(4):e13574.

Evans K, de Jong W, Cronkleton P, Sheil D, Lynam T, Kusumanto T and Colfer CJP (2006) *Guide to participatory tools for forest communities*, Center for International Forestry Research, Bogor, Indonesia.

Freeman RE (2010) 'Managing for stakeholders: trade-offs or value creation', *Journal of Business Ethics,* 96:7–9.

GoP (Government of the Philippines) (2015) *Executive Order No. 193: Expanding the coverage of the National Greening Program*, Government of the Philippines.

Grimble R and Wellard K (1997) 'Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities', *Agricultural Systems,* 55(2):173–193, doi:10.1016/S0308-521X(97)00006-1

Guiang ES, Esguerra F and Bacalla D (2012) 'Devolved and decentralized forest management in the Philippines: triggers and constraints in investments', in Colfer CJP, Dahal GR and Capistrano D (eds) *Lessons from forest decentralization: money, justice and the quest for good governance in Asia-Pacific*, Earthscan, London, UK, p. 163–185.

Higman S, Mayers J, Bass S, Judd N and Nussbaum R (2005) *The sustainable forestry handbook: a practical guide for tropical forest managers on implementing new standards*, 2nd edn, Earthscan Publications Ltd., Trowbridge, UK.

Holzknecht H (2017) 'Review of legislation and policies relevant to community forestry in Papua New Guinea', report of ACIAR project FST/2011/057, University of the Sunshine Coast, not published.

Jellinek S, Wilson KA, Hagger V, Mumaw L, Cooke B, Guerrero AM, Erickson TE, Zamin T, Waryszak P and Standish RJ (2019) 'Integrating diverse social and ecological motivations to achieve landscape restoration', *Journal of Applied Ecology,* 56(1):246–252.

Johansson EL and Isgren E (2017) 'Local perceptions of land-use change: using participatory art to reveal direct and indirect socioenvironmental effects of land acquisitions in Kilombero Valley, Tanzania', *Ecology and Society,* 22(1).

Lazos-Chavero E, Zinda J, Bennett-Curry A, Balvanera P, Bloomfield G, Lindell C and Negra C (2016) 'Stakeholders and tropical reforestation: challenges, trade-offs, and strategies in dynamic environments', *Biotropica*, 48(6):900–914, doi:10.1111/btp.12391.

Li T, Lü Y, Fu B, Comber AJ, Harris P and Wu L (2017) 'Gauging policy-driven large-scale vegetation restoration programmes under a changing environment: their effectiveness and socio-economic relationships', *Science of the Total Environment,* 607: 911–919.

Maginnis S and Jackson W (2007) 'What Is FLR and How Does It Differ from Current Approaches?', in J Rietbergen-McCracken, S Maginnis and A Sarre (eds) *The Forest landscape restoration handbook*, pp. 5–20, Earthscan, London, UK.

Mansourian S (2005) 'Overview of forest restoration strategies and terms', in Mansourian S, Vallauri D and Dudley N (eds) *Forest restoration in landscapes: beyond planting trees*, pp. 8–13, Springer, New York.

—— (2018) 'Stakeholders and forest landscape restoration: who decides what to restore, why and where?', in Mansourian S and Parrotta JA (eds) *Forest landscape restoration: integrated approaches to support effective implementation*, Routledge, London, UK.

Meli P, Martínez-Ramos M, Rey-Benayas JM and Carabias J (2014) 'Combining ecological, social and technical criteria to select species for forest restoration', *Applied Vegetation Science,* 17(4):744–753.

Osborne T, Brock S, Chazdon R, Chomba S, Garen E, Gutierrez V, Lave R, Lefevre M and Sundberg J (2021) 'The political ecology playbook for ecosystem restoration: principles for effective, equitable, and transformative landscapes', *Global Environmental Change,* 70:102320, doi:10.1016/j.gloenvcha.2021.102320.

Pulhin JM, Dizon JT, Cruz RVO, Gevana DT and Dahal G (2008) *Tenure reform on Philippine forest lands: assessment of socio-economic and environmental impacts*, Center for International Forestry Research, Bogor, Indonesia.

Sacande M, Parfondry M, Cicatiello C, Scarascia-Mugnozza G, Garba A, Olorunfemi PS, Diagne M and Martucci A (2021) 'Socio-economic impacts derived from large scale restoration in three Great Green Wall countries', *Journal of Rural Studies,* 87:160–168.

Sayer J, Margules C, Boedhihartono AK, Dale A, Sunderland T, Supriatna J and Saryanthi R (2015) 'Landscape approaches: what are the pre-conditions for success?', *Sustainability Science,* 10(2):345–355.

Sayer J, Sunderland T, Ghazoul J, Pfund J-L, Sheil D, Meijaard E, Venter M, Boedhihartono AK, Day M, Garcia C, van Oosten C and Buck LE (2013) 'Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses', *Proceedings of the National Academy of Sciences,* 110(21):8349–8356, doi:10.1073/pnas.1210595110.

Tiendrébéogo S, Ouedraogo A, Kabore R, Zougouri S, Elias M, Traore AT, Vinceti B, Traore D and Yago-Ouattara EL (2020) 'Enhancing women's rights and lives through gender-equitable restoration in Burkina Faso', *ETFRN NEWS 60: Restoring African drylands*, ISSN: 1876–5866.

UNEP and FAO (2021) *Principles for ecosystem restoration to guide the United Nations Decade 2021–2030*, FAO, Rome, Italy.

Wiset K (2022) *Engaging local people in forest landscape restoration: case studies in Eastern Visayas (the Philippines) and Ramu-Markham Valley (Papua New Guinea)*, doctoral thesis, University of the Sunshine Coast, Queensland, Australia, https://doi.org/10.25907/00674.

Wiset K, Fisher R, Baynes J, Wampe N, Thom M, Jackson W and Herbohn J (2022) 'What could forest landscape restoration look like in the Ramu-Markham Valley of Papua New Guinea?', *Land Use Policy*, 121:106322, doi:10.1016/j.landusepol.2022.106322.

Wiset K, Gregorio N, Fisher R, Mangaoang E and Herbohn J (2023) 'Assessing the effectiveness of the engagement of local people in restoring degraded forest landscapes in Leyte and Biliran Provinces, the Philippines', *Environmental Science & Policy*, 148:103545, doi:10.1016/j.envsci.2023.07.005.

Chapter 4

Understanding the dynamics of smallholders growing teak in northern Laos

Soytavanh Mienmany, Hilary Smith
and Peter Kanowski

Abstract

Teak growing by smallholder farmers boomed in parts of northern Laos in the 1980s and 1990s, promoted by the government and accelerated by peer influence. Most growers initially viewed tree growing as an opportunity to acquire land, planting and managing teak as a low-labour green bank, with minimal inputs and as-needed harvesting. These teak plantations were geographically dispersed, with growers relying on local traders to access neighbouring countries' markets for unprocessed logs or rough-sawn timber, and to supply domestic markets for low-quality timber products manufactured through value chains dominated by micro-, small- and medium-sized enterprises (mSMEs). Government promotional policies and support mechanisms for these low-value markets were not sustained. Recent national regulations are aimed at protecting natural forests, developing domestic processing, increasing value retention in Laos, and improving regulatory compliance. Unfortunately, the new policies have failed to account for smallholders and their operating contexts. Consequently, new boom crops with quicker returns and fewer regulatory constraints are displacing teak on more accessible and productive sites. The mismatch of new legality and certification requirements with famers' motivations and capability, competition with other crops, and low institutional capacity now limit the appeal of teak growing to smallholder farmers, paradoxically undermining what should be their comparative advantage. Thus, teak has proved to be both 'green gold' and fool's gold for farmers in northern Laos. While the area of teak in northern Laos remains relatively stable despite the lack of policy support, if smallholder teak growers and mSMEs are to flourish, renewed policy attention is required.

Acknowledgements

This work was conducted with the support of ACIAR project FST/2016/151 and informed by work conducted under ACIAR projects FST/2010/012 and ADP/2014/047. It draws primarily from the first author's PhD study at the Australian National University. We thank ACIAR, the Australian National University and the Australia Awards Scholarships for financial support, ACIAR project team members for their collaboration, other members of the first author's supervisory panel, and participants in the case studies for sharing their time and knowledge.

Introduction

Following the establishment of the Lao People's Democratic Republic (PDR) in 1975, forest resources were viewed as 'green gold' (*kham khieow*) and became the new government's primary source of revenue generation (Phengsopha 2015). As a result, exploitation of natural forests accelerated, resulting in rapid deforestation and degradation, eventually prompting successive policy interventions, such as moratoriums on logging and log exports (Lu and Smith 2023; Phimmavong et al. 2009), and the promotion of tree planting.

From the early 1980s, tree plantations – particularly of teak (*Tectona grandis*) – were promoted by the government and prioritised by national and provincial authorities as part of the development strategy for northern Laos (Hansen et al. 1997). Policy objectives were to promote self-sufficiency in plantation wood and to supply nascent wood-processing industries for domestic and export markets (Phimmavong et al. 2009). The subsequent expansion of teak growing in Laos has many of the characteristics of a crop boom, defined as 'taking place when there is a rapid increase in a given area in the amount of land devoted to a given crop as a monocrop or near-monocrop, and when that crop involves investment decisions that span multiple growing seasons' (Hall 2011:840). While boom crops are often associated with large-scale land acquisition or 'land grabbing' (Cramb et al. 2017; Hall 2011), smallholders have also been agents of crop boom transformations, in both northern Laos (Friis and Nielsen 2016; Santasombat 2019) and elsewhere (for example, Northern Myanmar (Hayward et al. 2020)).

Mapping of teak plantations in Luang Prabang Province of northern Laos using available remotely sensed imagery in 2018 and 2021 found that the area in 2014 was 19,300 ha, and almost identical, at 19,400 ha, in 2021; while 3,263 ha was converted to other uses in that period, another 3,352 ha of new teak was planted, balancing the loss. Plantation areas on lower slopes and closer to roads and villages were less likely to have been replanted with teak, in contrast to new areas which were more likely to have been established further uphill and more distant from roads and villages (Boer and Smith 2022).

Teak is typically planted by smallholder farmers in plots of less than one hectare each. Early extension material and regulations influenced how teak was planted, in particular the number of trees (stocking) and their spacing. Farmer-managed teak plots often suffer from poor plantation management in site preparation, lack of improved germplasm, and poor pruning and thinning, all of which constrain growth and product quality (Dieters et al. 2014; Race and Stewart 2016). Farmers typically do not thin their stands and harvest a few trees only when needed (Midgley et al. 2015; Newby et al. 2014). This means that most stands are maintained as trees of only small-diameter or medium-diameter class (Figure 4-1).

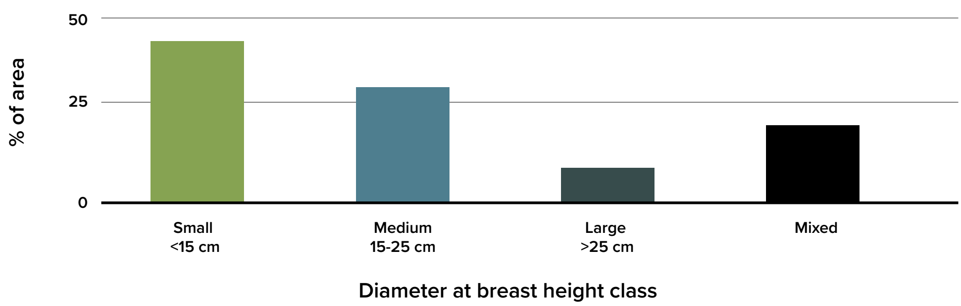

Figure 4-1: Percentage of teak area in Luang Prabang Province by diameter-size class, 2021

Source: Smith 2022

In this chapter, we describe research conducted in northern Laos between 2017 and 2019 to explore the dynamics of decision-making by farmers about teak growing, in the context of the 'opening up' of the Lao economy to international investment and markets (Hirsch and Scurrah 2015; Lienhard et al. 2019). As a result of this opening up, successive waves of boom crops have been fostered – mainly bananas (Friis and Nielsen 2016), cassava (Smith et al. 2018a), maize (Kallio et al. 2019), sugarcane (Sylvester 2018) and rubber (Lu 2017) – primarily by investments from the neighbouring countries of China, Thailand and Vietnam. Our research built on several studies of farmers' adoption of teak in Laos (Arvola et al. 2018; Newby et al. 2014; Smith et al. 2017) to better understand the reasons for farming households' decisions in the context of these crop booms, and the wider rural transformations underway in rural Laos (Rigg 2005, 2020).

Research overview

Farming households' decision-making

In response to the opening up of the Lao economy, many farmers have moved progressively from primarily subsistence to largely commercially oriented agricultural production, including through tree planting, with resulting changes to rural landscapes and livelihoods (Cramb et al. 2017; Newby et al. 2014; Rigg 2020). We focused on factors that influence farmers' decision-making about planting and continuing to grow teak, using the household as the focus of analysis.

Farmer decision-making is recognised as dynamic, multidimensional and contextual (Hermans et al. 2021) and researchers have developed various approaches for identifying and defining the factors that influence farmers' decisions. We drew from frameworks presented by Meijer et al. (2015), Pannell et al. (2006) and Versteeg et al. (2017) to develop a model representing factors that influence farmers' decision-making about teak growing (Figure 4-2). Following Versteeg et al. (2017), our model is structured around factors external to and within the village, and characteristics of the household. Key factors external to the village are government policies, market demand and crop characteristics. Factors within the village are peer effects and market chain networks. Household characteristics and livelihood strategies include security of land tenure, knowledge of tree growing and attitude to long-term investment.

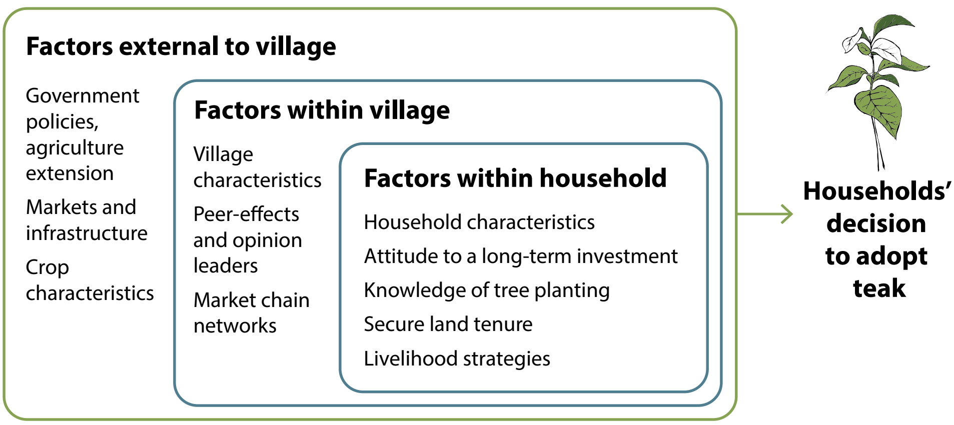

Figure 4-2: **Model representing factors that influence farmers' decision-making about teak growing (adapted from Versteeg et al. (2017))**

Below, we describe our research methods, before presenting our results in relation to each of these sets of factors and characteristics.

Research methods

Our research was conducted as part of an ACIAR forestry project (FST/2016/151, 'Advancing enhanced wood manufacturing industries in Laos and Australia') known as VALTIP3[9], which explored policies and processing technologies relevant to smallholder tree plantation species in Laos. Fieldwork was conducted in Luang Prabang Province, a region with a large area of planted teak and with geographic proximity to export markets in China and Thailand. We selected case study villages in 2 districts, one close to and the other remote from Luang Prabang city, the provincial capital and centre of economic activity. Criteria used to identify potential case study villages were the level of uptake of the teak (at least 20% of the farming population); household wealth (a range, from low to high); village population size (small to moderate to allow reasonable sampling); differential access to infrastructure and markets; and the village's willingness to participate in the research.

The 2 villages selected had populations of about 1,100 and 1,400 people; most (more than 80%) villagers were Khmu people; land areas were 1,200 ha and 2,000 ha; land uses were broadly similar (paddy rice, rubber, teak, some annual crops); and teak areas were 70 ha and 120 ha, respectively. Average total household landholdings were 5.41 ha and 8.30 ha, and the average teak areas among adopters were 1.88 ha and 3.45 ha.

The first author collected primary data over a period of one month in each village between June and August 2018, and supplementary and contextual information about actors, markets and policy as part of VALTIP3 value-chain studies of teak conducted in December 2017 (Smith et al. 2018) and of rubber conducted in June 2019 (Smith et al. 2020). Multiple methods were used to collect data – focus group discussions, household interviews, formal and informal discussions, field observations, and reviews of relevant secondary sources.

Of the 62 households surveyed – 32 in one village and 30 in the other – 40 were current teak growers; 4 had previously grown teak but withdrawn; and 22 had never grown teak. Teak-growing households were categorised as early (1990s or prior), intermediate (2000s) and late (2010s) adopters. Absentee teak owners are present in both case study villages, particularly in Village 1, where they own more than 50% of the teak area. In Village 2, approximately 30% are absentee owners. Interviews were confined to households that were resident in each village.

Results

The reasons that resident households gave for their decision to grow teak were largely consistent across villages (Figure 4-3). The most common reason given by almost two-thirds (63%) of teak growers interviewed was 'following others'. The next most common reasons for growing teak were 'DAFO (district agriculture and forestry office) promotion, including provision of free seedlings and training,' and 'long-term investment' – each given by more than a third (35%) of growers. Income generation and concerns that households would not be able to access wood from natural forests followed (23% each), slightly ahead of providing wood for household use (15%). Securing land (or 'booking' the land, as certain government programs allowed) was a consideration for many early adopters, but less so as land availability diminished.

9 VALTIP3 was the third in a series of ACIAR-funded projects that began in 2007 with a project titled 'Value-adding to Lao PDR plantation timber products' – VALTIP. The acronym has been retained in the second and third projects despite their slightly different objectives.

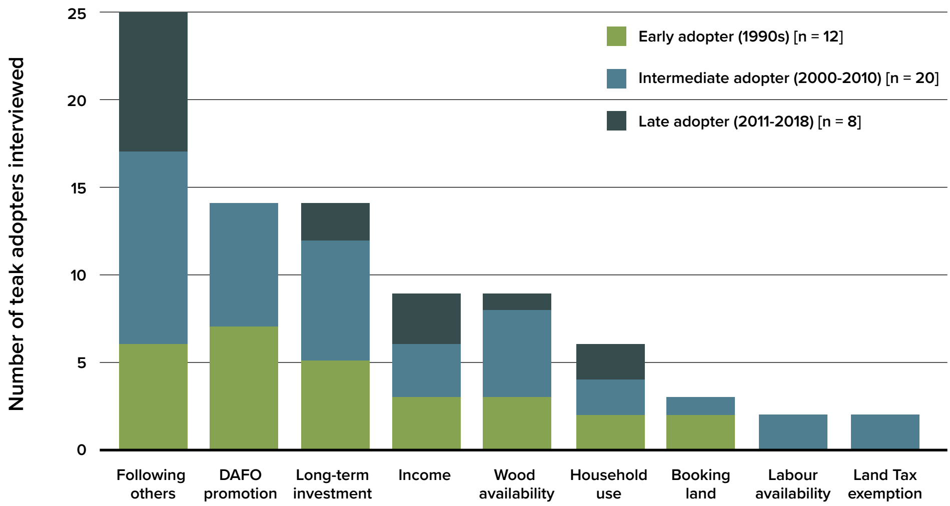

Figure 4-3: **Reasons that households in the 2 case study villages decided to grow teak (n = 40)**

The most common reason for not growing teak was 'land location,' with half of these households explaining that, while they had available land, it was too inaccessible. Other reasons included not having enough land or labour to devote to growing teak; the time to achieve income returns being too long; household members being too old; or not having access to seedlings (Figure 4-4).

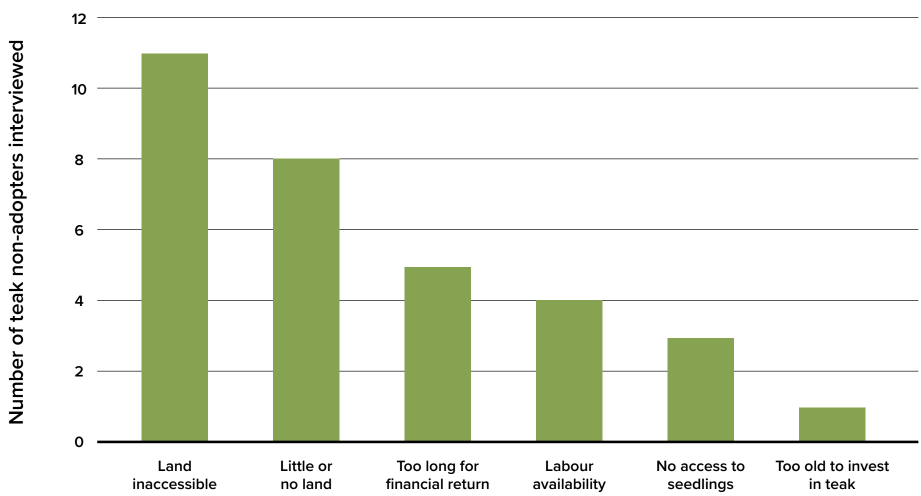

Figure 4-4: **The 6 most common reasons that households in the 2 case study villages decided not to grow teak (n = 22)**

Figure 4-2 presents the 3 categories of factors identified as influencing households' decision-making – factors external to the village, factors within the village, and household characteristics. We follow this with a discussion of the most significant of these factors (Table 4-1).

Table 4-1: **Summary of factors that influence households' decision-making about teak adoption, based on our literature review and research findings**

	Factor	Influence on adopters	Influence on non-adopters
Factors external to village	**Government policy**		
	Land and Forest Allocation Program Village consolidation Plantation promotion Land tax exemption	These policies were strong drivers of initial establishment by early adopters in both villages in the 1990s.	
	Markets and infrastructure		
	At the start, teak market price did not play a key role in influencing households to adopt teak. Domestic and export markets for teak remain steady.	Competitive teak prices and trader choices are now a key factor in adoption decisions in both villages.	
	Crop characteristics		
	Crop cycle and management system	Teak is fast-growing relative to most other high-value natural timber species; easy to propagate, grows fast in early years and tolerant to fire; ability to intercrop; perceived as low input.	
Factors within village	**Village characteristics**		
	Land availability Road accessibility	Land is within a short distance of roads and sufficient land is available for households to diversify their livelihood activities.	
	Peer effect		
	Respected elders with knowledge and experience in growing teak	Adoption decisions were more influenced by peers, in terms of 'following others'.	The perception of peers was that it takes 'too long to invest in teak.'
	Market chain network		
	A single trader (monopoly) Multiple traders	Households have little power to negotiate the teak price.	Low prices discourage households from adopting teak.
Factors within household	**Household characteristics**		
	Wealth categories, age, education, occupation, level of networking and access to information	All wealth categories represented, some households are well educated, have more land and off-farm income, have social networks within the village and with outsiders.	Middle, lower and poor wealth categories where households have little to no land and prioritise other cash crops that have faster returns.
	Knowledge and attitude		
	Households' perception of expected costs and benefits of growing teak and their attitude to a long-term investment	Households have seen teak as a 'green bank'; and benefit from incentives to claim land and land tax exemptions.	Even though teak is a secure asset for households, they prefer short-term return crops (maize, Job's tears, rubber).

Factors external to the village

Policies

The establishment of teak plantations in northern Laos was influenced primarily by the Lao PDR government's Land and Forest Allocation Program and promotion of tree planting during the 1980s and 1990s. These policies sought to increase forest cover by substituting timber harvested from natural forests with wood from tree plantations (Smith et al. 2017a) and by targeting replacement of traditional swidden practices in the uplands with permanent cropping (Castella et al. 2013; Fox et al. 2009; Hansen et al. 1997; Vongkhamchanh and Van der Heide 1989). Results confirm that these policies were influential, with more than a third (35%) of teak adopters attributing their decision to teak promotion programs (Figure 4-3). While the majority of the households mentioned 'following others' as one of their reasons for adopting teak, it is clear that policy drivers were particularly important for the early adopters. The role of DAFO officers in influencing their peers was also significant; in some cases, government officers adopted teak and then advocated others to follow.

Disentangling the direct influence of policies and other supporting factors is difficult, particularly where strong slogans were used. While households, for example, cite 'forest cover' as a reason for adopting teak, other factors may have proven more influential. These may include incentives for adoption, such as receiving land-use rights, land-tax exemptions, free seedlings or extension advice; or disincentives to continuing existing practices, such as shifting cultivation. To earn tax exemptions and legally harvest wood, households are required to register their plantations with DAFO (Smith et al. 2017b); yet, the majority of farmer teak plots remain unregistered, notwithstanding efforts by independent actors such as the Luang Prabang Teak Program to facilitate registration (Smith et al. 2017b).

These results for teak in Laos are consistent with the global pattern of state support for tree plantations (Scott 1998; Szulecka, Pretzsch and Secco 2014). In Laos and elsewhere in Southeast Asia, governments have promoted tree plantations as an alternative land use to traditional swidden agricultural systems (Castella et al. 2013; Ducourtieux et al. 2005). As one of the surveyed households mentioned: 'We planted teak because *pak-lat* [the party-government] do not allow us to slash and burn, they promoted tree planting' (fieldwork notes, 2018). This is similar to policies in neighbouring counties. In Thailand during the 1990s, the Royal Forestry Department promoted eucalypt plantations by providing incentives (free seedlings, fertiliser and soft loans) to smallholders (Barney 2004; Pousajja 1996). In Vietnam, the government promoted a tree plantation development scheme of eucalypts and acacias to improve people's livelihoods through a forest and land allocation program (Sikor 2012; Smith et al. 2017a).

In the past 5 years, however, a series of policy changes directed at strengthening legality and regulatory compliance in the Lao forest sector have affected teak growers and value-chain actors. We discuss these in later sections.

Markets

In Laos over the past 2 decades, rural households have shifted progressively from a subsistence to a market-based and export-oriented economy led by market 'pull', mediated by a series of Lao PDR government policies (De Koninck et al. 2012; Hirsch and Scurrah 2015; Kenney-Lazar 2012). Consequently, Laos has experienced several export-oriented crop booms in, for instance, cassava, bananas, maize, rubber and sugarcane. While policy drivers were initially influential in motivating the adoption of teak, the booming demand for industrial wood in Asia has sent positive and significant market signals for both large-scale and small-scale tree growing in Laos (Midgley et al. 2017, 2015; Smith et al. 2018b).

On the other hand, policy responses to the adverse outcomes of the rush for land, prompted largely by other boom crops, have created negative market signals, inhibiting plantation investments generally and constraining export wood markets. This has affected other plantation tree crops (Smith et al. 2020) as well as teak, with the rush to plant teak in the 1990s and 2000s slowing to such an extent that there has been little change in the planted area in recent years (Boer 2019).

Direct market demand for teak wood was not viewed by households in the 2 case study villages as an important factor in their adoption decision. Initially, most households had little market information; subsequently, perceptions of the adequacy and competitiveness of prices for teak became a factor in some decisions about whether to continue growing it or to switch to other crops. Teak markets in the 2 villages differed markedly. Those in Village 1 are controlled by a single trader, while households in Village 2 have a choice of traders. This market situation has had a significant impact on households' decision-making. In Village 1, no households are willing to grow more teak, and some current growers now plan to cut teak to grow other crops such as rubber, bananas or convert to pasture. In contrast, in Village 2, households are not only keeping existing levels, but are planting more teak.

Crop characteristics

A crop's 'biological and ecological characteristics' are important factors underpinning crop booms in Southeast Asia (Hall 2011:853). Teak has several characteristics as a crop that are relevant to its adoption in the case study villages. Teak is easy to propagate and fast-growing when compared to most other high-value natural forest species (Hansen et al. 1997), with only 15 to 20 years to commercial maturity (Arvola et al. 2018; Midgley et al. 2007; Newby et al. 2012; Smith et al. 2017a). Free seedlings were provided by the Lao PDR government during the plantation promotion program from the 1980s to the early 2000s, facilitating its promotion and adoption. As a long-lived tree with wood that appreciates in value over time, teak allows growers to retain their trees until they choose to harvest, with no imperative to harvest because of decline in product quality, as occurs with most agricultural crops. Other studies have shown that teak has contributed to a 'livelihood transition' from subsistence-oriented swidden agriculture to more market-oriented farming systems (Newby et al. 2012). Farmers who adopted teak have done so to enhance their assets and future income. Smith et al. (2017b) found that selling teak wood represents only a very small proportion (7%) of annual household income, suggesting that other factors are more important in management decisions. In contrast, in neighbouring Myanmar the commercial attractiveness of teak and a desire to enhance overall profitability from land were foremost in farmers' decision to adopt teak (Nair and Souvannavong 2000).

The Lao PDR government's teak promotion program was important in informing households of teak as a high-value and durable timber that can be used by households for house and furniture construction instead of wood from native forests. With appropriate management, teak also yields useful secondary products; households use young teak branches from pruning and thinning for fuelwood and fencing – also reported for Laos by Hansen et al. (1997) and Midgley et al. (2017), and for Indonesia by Roshetko et al. (2013). Another advantage of teak is its suitability for intercropping, which is commonly practised by households in the 2 villages with upland swidden crops (rice, maize and Job's tears) during the first 1 to 3 years of the plantation. This generates food and/or income for households and controls weeds for the young teak. These results are consistent with those of other studies of teak in northern Laos by Arvola et al. (2018), Dieters et al. (2014), Newby et al. (2012) and Pachas et al. (2019); and in Java, Indonesia, where Khasanah et al. (2015) reported maize intercropping with teak for the first 5 years of teak growing.

Generally, households in both villages viewed teak as easy to grow and a low-labour crop. Similarly, in Thailand cassava farmers shifted to eucalypt plantations because of their short rotation (5 to 7 years), capacity to grow in poor soil conditions after repeated cassava crops, and low-labour inputs (Boulay et al. 2012). However, research results, such as those reported by Dieters et al. (2014) for northern Laos, show that maximising the value of teak requires thinning and pruning, which demand more time and labour than households typically commit. Farmers' perception of teak as a low-labour input crop results in them receiving a lower price than anticipated. This, in turn, flows on to affect other's opinions about whether or not to adopt teak.

Factors within the village

Village characteristics

Key village characteristics influencing household decisions to grow teak were the availability of suitable land and the security of land tenure. Our results show that teak adoption started with households who already owned or had access to suitable land that was not required for other crops, followed by those who used teak planting to secure land tenure by 'booking' it, as the Land and Forest Allocation Program and the Village Relocation and Consolidation Strategy allowed. This is consistent with other studies in Laos (Arvola et al. 2018; Hansen et al. 1997; Newby et al. 2012; Roder et al. 1995; Smith et al. 2017b) and elsewhere; for example, eucalypts in Thailand (Puntasen et al. 1992); eucalypts and acacias in Vietnam (Sikor 2012); and teak in Ghana, where Narh (2019:51) reported that farmers 'use teak as a political tool to secure their right to land'. Security of tenure has long been recognised as one of the 'keys' to smallholder tree growing (Byron 2001), but these results show that in some cases tree growing can also facilitate, rather than just depend on, such tenure security.

Figure 4-5: Mosaic landscape of teak-rice-maize and young fallow, Ngoi district, Luang Prabang Province, Laos, 2018

Credit: Soytavanh Mienmany

This strategy was not, however, available to all. Late adopters in both case study villages did not have land available for growing teak because it had already been 'booked' by others, or was already allocated, occupied by other households, or zoned for conservation. Similarly, elsewhere in northern Laos, early settlers had the opportunity to access the most fertile fields in upland and lowland areas, while new settlers missed out on this opportunity (Castella et al. 2013). In central Laos, farmers who had access to more land during the land booking period ('prior *chap chong* claims') had better opportunity to adopt agroforestry (van der Meer Simo et al. (2020:1,940). In Thailand, Boulay et al. (2012) reported that early settlers during the mid-1990s had the opportunity to secure land through eucalypt planting, but this was no longer possible by the time of their study. Over the last decade, one change for the worse in terms of land tenure security for local teak smallholders has resulted from many of them selling or transferring their teak and land to outsiders, as Newby et al. (2012) also reported. Consequently, this teak land was removed from the village's land pool, thereby reducing the village's capacity to allocate land in the broader community's interest (for example, to newlyweds).

A second important village characteristic was that of accessibility to markets and government services. Hansen et al. (1997) pointed out that, as of the 1990s, the distribution of teak in Luang Prabang Province was limited by the availability of transportation and that 95% of teak plantations were established along roads and rivers. Updated data on teak coverage for this province found that the majority of teak remains planted along these access routes (Boer and Smith 2022).

Infrastructure, mainly road access, and their condition and distance to Luang Prabang city differed significantly between the 2 case study villages. While Village 1 is relatively close to the city via a highway-quality asphalt road, Village 2 is further from the city and relies on boats and, until recently, dirt roads and transport of teak wood along the river. Nevertheless, farmers in Village 2 continue to adopt teak, reflecting a range of other factors.

Village characteristics also affect how households received information and agricultural extension. Households in Village 1 had more interaction with DAFO staff and therefore more teak information than those in Village 2. As a result, households in Village 2 had a higher proportion of households 'following others' in their village than in Village 1. This is discussed further below.

Peer effects and opinion leaders – 'following others'

'Following others' was the main reason (63% of respondents) households gave for teak adoption across the 2 villages (53% and 71% for Villages 1 and 2, respectively), and was particularly important for the middle and late adopters (see Figure 4-3). Peer effects have also been reported to be important in adoption of other crops in Laos. Friis and Nielsen (2016:126) found that one of the main reasons that households decided to lease their land to foreign companies for banana plantations in northern Laos was because they wanted to 'follow the society's development'. Similarly, Junquera et al. (2020) and Smith et al. (2020) found that following others was a significant factor in the adoption of rubber plantations in northern Laos during and after periods of rapid expansion, but – similar to these results for teak – not in the early stages of adoption.

In both villages, the influence of respected and, mostly wealthier, elders with knowledge and experience in growing teak was important in the dissemination of information and in influencing other households to adopt teak. These informal leaders shared information provided by government extension services, first with their relatives through an 'elder effect' and later to others in the village through 'peer effects'. Later-adopting households reported that they obtained knowledge mostly from their peers, rarely receiving information about teak from extension services. Arvola et al. (2019) reported similarly for tree growers in Tanzania, with most farmers obtaining knowledge of tree growing and plantation management from their families or other villagers, and very few from agricultural extension agents.

Market chain networks

While the overall market for teak has proven relatively stable in northern Laos (Midgley et al. 2015; Smith et al. 2018b), it is expressed differently in the 2 case study villages, primarily due to the different roles of teak traders in each. Traders play a critical role in connecting tree growers to markets in Laos (Midgley et al. 2015) and in Southeast Asia more widely, as Nuberg et al. (2019) reported for Nepal, and Sikor (2012) reported for Vietnam, where locally based traders predominate.

The 2 villages offer contrasting examples of the roles that traders can play in influencing households' decision-making on planting teak. In Village 1, where one trader monopolises the market and controls prices, farmers are no longer adopting teak, in part because they believe they are not receiving an adequate or fair price for the wood. This contrasts to Village 2, where several traders operate, leading to greater, although still limited, price competition. Households there have more choice of teak traders, and perceptions of inadequate or unfair prices do not constrain decisions to reinvest in teak growing. Teak price negotiations appear rare in both villages; rather, traders set the price, as reported by Arvola et al. (2018) and Smith et al. (2018b). While some households are able to refuse an offer from traders by delaying a sale, this course of action may only be open to those who are not in urgent need of income.

Traders play an important role in household adoption of teak as well as in market interactions (Smith et al. 2018b) and in helping farmers navigate regulatory hurdles. Households in the case study villages received little, if any, information and support from government agencies about teak markets and prices. When asked how they knew about teak prices, all households responded, 'from traders and peers' (fieldwork notes, 2018).

Efforts have been made to strengthen farmer's capacities and negotiation powers, as well as assist in market access, through for instance, the formation of grower groups, enterprises and forest certification. The donor-supported Luang Prabang Teak Project has been engaged in a sustained effort since 2008 to overcome some of these hurdles in the teak sector in Luang Prabang. Teak grower groups and enterprises have been established but have not been effective due to lack of trust among members, the administrative costs (in time and money) in registering groups and enterprises, and irregular teak supply (Ling et al. 2018). Furthermore, the complex requirements for plantation registration and sales processes, and for meeting certification standards, has meant that the benefits of complying or participating did not outweigh the cost (Smith et al. 2017b). Grower groups that have tried to access export markets have been inhibited by powerful domestic wood processors and strict export product standards introduced since 2016 (Smith et al. 2018b), as described below.

Factors at household level

Household characteristics and wealth

Household wealth is a major driver of participation in teak growing. In the case study villages, wealthier households were more likely to adopt teak; that is, those with more land overall as well as land suitable for teak growing, and those with higher incomes, including through off-farm activities or through being employed as service providers. This result is consistent with those of other studies in northern Laos (Arvola et al. 2018; Dieters et al. 2014; Newby et al. 2014). Similar results have been reported elsewhere. Boulay et al. (2012) found that Thai households with suitable and available land are more likely than others to adopt eucalypt tree farming. In Vietnam, Sikor and Baggio (2014) also found that better-off households are more likely to grow trees and invest in plantations than poor households.

Households were unable to adopt teak where they had unsuitable land – typically a long distance from roads – or were landless, even though they might express a desire to do so. This corresponds with earlier findings by Newby et al. (2014). In contrast, non-adopters who had suitable land opted to plant rubber or other crops on the grounds that it gave them a faster return than teak. Some teak-growing households were also 'withdrawing' to take up these opportunities, as Smith et al. (2020) reported in relation to the transition from teak to rubber in the same district as Village 1. As noted in our introduction, other shorter rotation crops can offer more profitable alternatives for farmers. Switching between crops is common among farming households; for example, in Luang Namtha Province, households are converting from rubber to bananas by leasing land to banana companies (Vongvisouk and Dwyer 2017), and pursuing other production options such as cattle. For teak, which is a crop with a long rotation, the decision to 'withdraw' or 'withdraw early' has important implications for those households that adopted it as a household savings strategy or 'green bank', as well as for the forests sector generally.

Young household heads are now less likely to adopt teak than older people, as evident in the small number of surveyed households in the 'late adopter' category. This was variously due to limited land availability, competition from other attractive crops (rubber, maize, Job's tears) and off-farm activities (notably, shops and food stalls), and to young family members migrating to work in Luang Prabang city rather than staying to work on the farm. Most older household heads explained that they had planted teak for their children and a few mentioned that they are now too old to adopt teak and will leave the next land-use decision to their children. This is consistent with results reported by Perz and Walker (2002), who found that stages of household life cycle may influence land-use decisions, and that younger households are more likely to focus on faster returns from their investments.

Knowledge of teak growing

Most early adopters and some intermediate adopters received information on teak planting through DAFO's extension services and most of those who adopted later learned from their peers. The most common statement from teak households was 'teak is easy to grow, I just look [for direction/knowledge] at other people's plots' (fieldwork notes, 2018). Informal discussions with households also found that some households did not even ask their neighbours how to plant teak; rather, they simply observed. Most teak adopters reported a perception that teak needed intensive labour inputs during only the first 3 years after planting. Another common perception was that planting many trees provides greater log volume, with some households planting at 1 m × 1 m spacing. This mindset meant they were hesitant to cut out small teak trees because they believed that all trees would continue growing. These practices stand in contrast to early extension advice and more recent research (Dieters et al. 2014; Newby et al. 2014) which recommends optimal teak planting spacing of 3 m × 3 m. Both wider initial spacing and more intensive management involving pruning and thinning would lead to better wood log quality and prices, and higher income overall (Dieters et al. 2014; Newby et al. 2014). A study of household perceptions of tree investments, particularly of labour in Java, Indonesia, also found that most smallholders fail to realise the potential of the silviculture required to meet market specifications (Irawanti et al. 2014) and achieve a better net return for their households. In many teak plantings in Laos, it is now too late to undertake management that will significantly increase the value of logs.

Figure 4-6: Riverside log landing near Luang Prabang, Laos, 2017
Credit: Hilary Smith

Livelihood strategies

Livelihood strategies of teak households in the case study villages are similar to those of most rural households in Laos; that is, households diversify their livelihoods to the extent that is possible and affordable. Depending on individual circumstances and opportunities, these strategies typically comprise growing food crops for subsistence and sale, growing trees, rearing livestock, and labouring or providing services on farm and off farm. This holds true for smallholder tree growers in many countries. For example, in Java, Indonesia, small-scale forestry is commonly seen as an integrated component of family farms (Irawanti et al. 2014). In Tanzania, farmers have adopted tree growing as a tool for diversifying their livelihoods (Arvola et al. 2019).

As Rigg (2006) noted, rural households in Laos have diversified their livelihoods both for survival and to build wealth, resulting in what Rigg et al. (2020) describe for neighbouring Northeastern Thailand as a 'hybrid household', where most households are multifunctional and drawing income from a range of on-farm and off-farm activities. This is a widespread phenomenon, both in relation to tree growing and more generally. For example, households in Thailand planted eucalypts to diversify their income (Boulay et al. 2012). McCarthy (2019:4) and Pritchard et al. (2017:52) reported strategies adopted by rural households in Indonesia and India, respectively, that were characterised by moving 'sideways' to off-farm activities, while retaining their activities on farm. They suggest that many households are just moving sideways, or treading water, in a stalled agrarian transition, in which they continue to have certain vulnerabilities, including problems accessing nutritious food.

Figure 4-7: Square logs, Ban Xieng Lom, Luang Prabang Province, Laos, 2016

Credit: Hilary Smith

Some households in both case study villages valued the 'long-term investment' dimension of teak growing, but teak adoption in these villages is diverging, for the reasons discussed in preceding sections. In Village 1, teak planting has ceased, and the village landscape is now characterised by mature teak and rubber, young rubber, short-cycle crops (Job's tears and maize) and paddy rice. In Village 2, about 20 households are establishing new teak plantations, and the village landscape is characterised by young teak (1–2 years old) growing close to roads, maize, mature rubber, upland rice and small areas of paddy rice. Although Village 1 has good road access to markets, the presence of a monopoly trader and alternative crops means that households are no longer interested in growing teak. In contrast, in Village 2, access is poorer, by dirt road and by river, but households continue growing teak because they feel that they receive a fair teak price with more competition among teak traders.

The majority of households in both villages would now prefer to plant rubber than teak because of the faster returns, and because rubber provides a fortnightly return 8 to 10 years after planting, if tapped regularly (Smith et al. 2020). On the other hand, some households mentioned that investing in rubber requires high inputs, and they needed to have secure income while waiting for the rubber to mature. Those households unable to afford to invest in rubber preferred to cultivate annual crops such as maize, rice and Job's tears. This result is consistent with those reported by Maraseni et al. (2018) for smallholder teak in Xayabouly Province, and by Arvola et al. (2018) for Luang Prabang Province, where farmers planned to convert their teak plots and use their labour for more productive land uses that provide more regular returns, such as high-demand tropical fruit crops.

Our results suggest that, overall, households that own teak are wealthier than those that do not. This finding is consistent with other research on teak smallholders in Laos, which found that initial household wealth was an enabling factor for wealth accumulation, including for those teak households who had planted but not yet harvested teak, compared to those households that had never planted teak. Similarly, households that had planted and harvested some trees tended to have greater wealth than households that had planted but not yet harvested any trees. More generally, teak-owning households are typically relatively wealthy, have a higher education level and are more likely to be employed in the public service (Cramb et al. 2017; Newby et al. 2012).

Emerging themes

Policy challenges for teak value chains

Our results confirm that past forest and land allocation policies were instrumental in initiating and stimulating early adoption of teak growing in northern Laos, but that subsequent uptake was driven more by peer influence. Market participation was a lesser motivator, although the value of trees as a 'green bank' from which households could draw for emergencies and significant costs was also important. Farmers' mainly ad hoc participation in timber value chains means that they largely operate in the informal sector, opting out – either intentionally or innocently – of compliance with relevant regulations (Smith et al. 2017b). When farmers do need to sell teak, they are highly dependent on traders and micro-scale and small-scale enterprises, which may also be informal, to access markets. Incentives for compliance have not proven effective. Although households who register their trees are entitled to land tax exemptions, implementation of the exemption varies, and teak smallholders in both case study villages continue to pay land tax for their teak plots. Smallholders seem to pursue and achieve plantation registration only when it is catalysed by an external agency, such as the Luang Prabang Teak Project.

However, these constraints do not seem to have affected the overall level of teak planting, which, as noted above, remains stable (Boer 2019), suggesting that this policy measure may be ineffective (Smith et al. 2017b). It has nevertheless been retained in the newly reformed Forestry Law (No. 64/NA 2019), through which the Lao PDR government is increasingly regulating and enforcing taxation of income, including from forestry businesses and plantation growing[10] (Smith 2021). Smith et al. (2018b:38) pointed out that taxes in teak value chains 'remain a significant and often unclear and inconsistently applied financial constraint' and encourage participation in the informal sector. It remains to be seen how these reforms will be implemented and enforced, or what the impacts on tree growing will be.

In 2016, the Lao Prime Minister's Order (PMO15) on Enhancing Strictness on the Management and Inspection of Timber Exploitation, Timber Movement and Timber Business banned the export of all unprocessed wood, included teak and other plantation species. It had immediate impacts on markets and prices for teak growers who exported logs directly to neighbouring countries (Smith et al. 2018b). While the ban was not aimed at farmer-grown teak, it nevertheless sent strong negative signals to the plantation and wood-processing sectors. It also catalysed a review of all processing enterprises, closing many micro-scale and small factories operating informally (Smith et al. 2020), and which had been key markets for many farmer growers (fieldwork notes, 2018). As a species that occurs naturally in Laos, teak remains constrained by the new log export rules, despite policy reforms enabling export of other plantation-wood species.

While current agricultural and forest sector policies and strategies include statements of support to mSMEs and to partnerships with bigger business (see, for example, MPI 2021), it is not yet clear what forms these partnerships might take, what incentives might apply, or how the small-scale sector will benefit. In practice, micro-scale and small-scale actors are peripheral to current policy focuses and initiatives. As Cramb et al. (2017:940) noted, any 'smallholder-oriented development strategy' is unlikely to be realised without more effective polices to enable and support smallholders and other small-scale actors.

10 See, for example, the chapter on Forestry Enterprises in Smith (2021) and the new Income Tax Law No. 67/NA dated 18 June 2019.

Figure 4-8: **Teak enterprise, Ban Xieng Lom, Luang Prabang Province, Laos, 2016**
Credit: Ken Boer

Institutional capacity for implementation remains constrained in Laos. The potential benefits to farmers and value chains from early successes in fostering teak growing have not been fully realised, leading to a resource base that is suboptimal for value recovery and non-compliant with regulatory requirements. To achieve national policies, a more concerted and effective focus on enabling smallholders and mSMEs is necessary, both in partnership with and independent of larger-scale businesses. Examples of successes in these terms within the region (Arnold et al. 2022) could prove translatable into the Lao context.

Market challenges

Historically, local, usually informal, market chains have provided the most attractive options for smallholders to sell their wood. Local traders provide immediate payment for wood sales and sometimes obtain the approvals needed, which smallholders find burdensome at best, or perhaps impossible. The regulatory changes noted above are reshaping market opportunities and the smallholder teak sector now faces market challenges beyond those common to all smallholder growers (Smith et al. 2017b). The main challenge is the operating environment likely to be shaped by the European Union (EU) – Laos Voluntary Partnership Agreement (VPA), or successor arrangements aimed at curtailing deforestation and forest degradation associated with supply chains (EU 2022). The second challenge relates to certification as a market-based instrument.

The EU–Laos VPA seeks to advance trade in legal timber and strengthen forest governance and sustainable forest management by promoting participatory processes and inclusive policies for all stakeholders. The proposed EU regulation on deforestation-free products will require due diligence in all timber supply chains linked to member countries' markets. It is expected that the EU–Laos VPA process and deforestation-free regulation will increase private sector capacity to participate in the production, marketing and trade of legal timber. The VPA also seeks to improve the enabling conditions under which the timber industry operates.

In this context, Timber Legality Definition No. 3 under the EU–Lao VPA standardises and formalises the processes of producing legal plantation-grown wood. It will apply to all types of plantations and planted trees, from scattered plantings to large-scale monocultures. The Lao small-scale plantation sector is diverse, with many actors, from thousands of smallholders to hundreds of mSMEs. Many operate informally and it is difficult for the government to recognise them as legitimate and include them in consultation processes. Groups representing smallholder producers are rare and there are cultural and historical barriers to forming groups. Private sector organisations do not represent smallholders or mSMEs. Instead, smallholders tend to be represented by civil society organisations, which focus on issues relevant to other marginalised groups. In the context of these consultative processes, therefore, smallholders have an identity crisis. They are considered neither true private sector enterprises nor part of civil society – as a result, they are largely invisible in the process.

Failure to understand and make reforms specifically for the small-scale sector risks further marginalising smallholders from legal timber markets. Economic opportunities will be lost. Recent reforms, such as plantation registration, are yet to be effective in addressing key legal barriers for many smallholders. Most small-scale plantations remain unregistered and, as a result, the source of their wood cannot be legally verified. If excluded from legal markets, smallholders may become discouraged and move out of tree growing and into the production of other crops. While other countries in the region have successfully simplified the procedures for the small-scale sector, including through self-declaration or group-declaration mechanisms and digital solutions, the Lao PDR government remains uncertain about these.

Figure 4-9: **Teak woodlot, Ban Pak Ou, Luang Prabang Province, Laos, 2017**

Credit: Hilary Smith

Voluntary measures

The Lao PDR government recognises the value of voluntary measures, where initiatives are led by the private sector in response to market, consumer, shareholder and broader community concerns. Voluntary measures are based on an assumption that private-sector-led action will improve market share or price.

However, for smallholders, forest certification is an even bigger hurdle than legality verification (Ling et al. 2018) and the formation of groups has not proven effective in scaling up smallholder participation in certification. Although smallholder plantations are generally 'low risk' in relation to certification criteria, the benefits of certification in relation to its costs are often unclear (Flanagan et al. 2019). While there are co-benefits to certification, such as increased awareness of regulatory requirements and improved plantation management practices, smallholder growers are seldom able to bear the costs directly.

Evolving markets

Smallholders generally lack knowledge of market prices, demand and quality requirements, which leads to a cycle of under-investment in tree growing. Better knowledge of market chains could allow farmers to make more informed decisions about participation in markets for forest products (Race and Stewart 2016). Improved market chain relations 'are expected to yield tangible benefits in terms of economic performance', so this has become a strategy used by many development agencies to reduce poverty (Donovan et al. 2015:3).

As markets for legal and certified-sustainable wood grow, smallholder teak plantations risk becoming 'stranded assets' because they are unable to comply with new regulations. Stranding smallholder assets will have negative impacts on the livelihoods of those who have invested in them, with consequences along the supply chain. If the value of their assets is not realised, this may also discourage future participation in tree growing, as alternative commodity crops become more attractive. A range of smallholder-focused measures are needed to address this situation. These could include revising the regulatory framework for smallholders and mSMEs to facilitate compliance, including targeted consultation and testing of regulations; running information campaigns in conjunction with incentives for compliance; encouraging and supporting group formation; and developing accessible digital solutions. The promotion of partnerships between small-scale and larger sector actors must be supported with measures to ensure contracts are fairly negotiated and are mutually beneficial.

Competition for land

As the Lao economy has opened up, and as regional and global demand for agricultural products has increased, smallholder farmers in Laos have been presented with opportunities to participate in a series of export-oriented crop booms, as noted in the introduction. The major benefits of households participating in teak growing have been as a low-labour-input means of securing land, plus using standing trees as a long-term investment and 'green bank'. These benefits, however, have become less appealing as alternative shorter harvest-cycle crops (for example, banana, Job's tears, maize, pineapples, rubber) were introduced into villages where land was no longer abundant. Nevertheless, the 'green bank' attributes of teak and its low-labour-input management remain attractive to some households, especially to absentee landowners. Additional pressures on land in parts of Luang Prabang Province and elsewhere in northern Laos are associated with infrastructure development and related population growth. Farmers close to growth centres gain the opportunity to sell-out and exit agriculture in favour of off-farm employment.

Lessons for smallholder forestry elsewhere

In the almost 50 years since the establishment of the Lao PDR, smallholder farmers have experienced a series of dramatic changes – postwar recovery, a brief period of collectivisation, a largely-closed economy and, now, substantial international investment into what is perceived as a 'land rich' nation bordering some of Asia's most dynamic economies.

The first phase of policy-led teak growing helped those with access to surplus land to establish long-term assets, in the form of both land and trees. Teak ownership is now distributed across all but the poorest households, but the greatest benefits have accrued to the wealthier households and to absentee owners, as observed more widely in many rural transformations (Newby et al. 2014; Cramb et al. 2017). The perceived benefits of teak as a low-labour-demanding green bank are available to, and valued by, farmers, and underpin continued teak growing. In this context, the retreat of teak to areas of lower opportunity-cost of production, in the face of a wider array of agricultural cash crops, is unsurprising. This suggests that enabling policy, supported by formal and informal extension processes, can catalyse tree growing. A related lesson is that follow-up extension and support services are needed if farmers are to optimise value from their trees.

Added to this, policy development and implementation needs to be sufficiently nuanced to recognise the differences between large-scale and small-scale actors. In the Lao case, recent policy measures focused on larger-scale actors have largely been blind to the impacts on smaller-scale actors, to the latter's significant disadvantage. This may again be the case in a current initiative to make degraded forest land available for large-scale plantations. A critical role could be played by mSMEs in smallholder-based value chains, even where – as, for example, in Vietnam – the ultimate processor is a large-scale industry. The scale and flexibility of mSME operations – both traders and primary processors – are well-matched to those of smallholder growers.

Figure 4-10: Mosaic landscape of teak-rice-maize and young fallow, Ngoi district, Luang Prabang Province, Laos, 2018

Credit: Soytavanh Mienmany

More recent market-led drivers of household decisions demonstrate that, even on sites where trees remain the best option, tree crops with a relatively long return are being displaced by crops with a faster return. The assessment of teak in Luang Prabang demonstrates that this does not necessarily mean that the area of a tree crop will diminish, but the location of stands in the landscape will change. The transition to other crops will be accelerated when, as is the case in Laos and almost universally, trees are more regulated than agricultural crops. This suggests a third lesson – that the regulatory environment for different crops should be as neutral as possible.

In rural communities, local factors will always be important. The suppression of competitive markets by a monopoly trader in one case study village, and the resulting adverse consequences for teak growing, illustrates how powerful hyperlocal factors can mediate policy and market forces. As a counter, the rise of digital technologies for agricultural market information and transactions illustrates how these constraints might be overcome.

Lastly, these results reiterate the capacity of smallholder farmers in dynamic contexts, such as those evident in Laos, to respond to changing circumstances and opportunities. As more of them become hybrid households (as defined by Rigg (2005) and Rigg et al. (2020)), low-labour-input crops such as teak may again become more attractive. This suggests that governments and the forest industries should continue to seek niches for tree growing where it fits well with household livelihood portfolios, ensuring that this option remains open for farmers as they navigate crop and land-use choices that intersect in complex ways with household characteristics and circumstances.

Conclusions: is teak in northern Laos green gold or fool's gold?

Teak has been green gold – on a modest scale rather than a gold rush – for many farmers in northern Laos. Its value has been as a green asset, in its own right, and as a means of securing land from which greater value can subsequently be realised. However, for other farmers the returns from teak have been disappointing, reflecting varying combinations of suboptimal management, distorted markets, and informal operations in an increasingly regulated environment. These factors have undermined teak's potential to anchor these smallholders' livelihoods, just as plantation investments anchor superannuation funds elsewhere. While teak is being displaced from lands where farmers have more profitable options, the differences in regulatory burden for teak compared to other crops and value chains means that, until the policy context changes, northern Laos is likely to have reached 'peak teak.' Consequently, the potential benefits of a more substantial and resilient teak sector economy are unlikely to be realised.

These results demonstrate how policymakers need to remain focused on the drivers of smallholder farmer and mSME decision-making, and not allow these actors to be treated merely as collateral in policy development that seeks to encourage larger-scale investment and economic transformation. As elsewhere, farmers in northern Laos are not fools – but nor can they pursue green gold if policy and market forces are arrayed against that element of their livelihood portfolio.

References

Arnold R, Midgley S, Stevens P, Phimmavong S, Kien ND and Chen S (2022) 'Profitable partnerships: smallholders, industry, eucalypts and acacias in Asia', *Australian Forestry,* 85:38–53.

Arvola A, Anttila J-P and Hogarth N (2018) 'By accident or by design? influence of government policies on drivers and barriers of smallholder teak growing in Lao PDR', *Forests, Trees and Livelihoods,* 28:34–51.

Barney K (2004) 'Re-encountering resistance: plantation activism and smallholder production in Thailand and Sarawak, Malaysia', *Asia Pacific Viewpoint,* 45:325–339.

Boer KJ (2019) *Advancing enhanced wood manufacturing industries in Laos and Australia: Luang Prabang Province teak inventory*, report produced for ACIAR project FST/2016/151 'Advancing enhanced engineered wood products in Lao PDR and Australia', Australian Centre for International Agricultural Research, Canberra, Australia (not published).

Boer KJ and Smith HF (2022) *Evaluation of growth and yield information for plantations in Laos*, report produced for ACIAR project FST/2016/151 'Advancing enhanced engineered wood products in Lao PDR and Australia', Australian Centre for International Agricultural Research, Canberra, Australia (not published).

Boulay A, Tacconi L and Kanowski P (2012) 'Drivers of adoption of eucalypt tree farming by smallholders in Thailand', *Agroforestry Systems,* 84:179–189.

Byron N (2001) 'Keys to smallholder forestry in developing countries in the tropics', in Harrison S and Herbohn J (eds) *Sustainable farm forestry in the Tropics*, Edward Elgar, Cheltenham, UK.

Castella JC, Lestrelin G, Hett C, Bourgoin J, Fitriana YR, Heinimann A and Pfund J-L (2013) 'Effects of landscape segregation on livelihood vulnerability: moving from extensive shifting cultivation to rotational agriculture and natural forests in northern Laos', *Human Ecology,* 41:63–76.

Cramb R, Manivong V, Newby J, Sothorn K and Sibat PS (2017) 'Alternatives to land grabbing: exploring conditions for smallholder inclusion in agricultural commodity chains in Southeast Asia', *The Journal of Peasant Studies,* 44:939–967.

De Koninck R, Rigg J and Vandergeest P (2012) 'A half century of agrarian transformations in Southeast Asia, 1960–2010', in Rigg J and Vandergeest P (eds) *Revisiting rural places: pathways to poverty and prosperity in Southeast Asia,* NUS Press, Singapore.

Dieters M, Newby J, Cramb R, Sexton G, McNamara S, Johnson MM, Sakanphet MS, Sodarak MH, Kikeo M and Savathvong MS (2014) *Enhancing on-farm incomes through improved silvicultural management of teak in Luang Prabang Province of Lao PDR*, Final report for ACIAR project FST/2004/057, ISBN 978 1 925133 14 1, Australian Centre for International Agricultural Research, Canberra.

Donovan J, Franzel S, Cunha M, Gyau A and Mithöfer D (2015) 'Guides for value chain development: a comparative review', *Journal of Agribusiness in Developing and Emerging Economies,* 5:2–23.

Ducourtieux O, Laffort JR and Sacklokham S (2005) 'Land policy and farming practices in Laos', *Development and Change,* 36:499–526.

EU (28 June 2022) *Council agrees on new rules to drive down deforestation and forest degradation globally* [media release 617/22], Council of the European Union, accessed 14 September 2023.

Flanagan AC, Midgley SJ, Stevens PR and McWhirter L (2019) 'Smallholder tree-farmers and forest certification in Southeast Asia: productivity, risks and policies', *Australian Forestry,* 82:18–28.

Fox J, Fujita Y, Ngidang D, Peluso N, Potter L, Sakuntaladewi N, Sturgeon J and Thomas D (2009) 'Policies, political-economy and swidden in Southeast Asia', *Human Ecology: An Interdisciplinary Journal,* 37:305–322.

Friis C and Nielsen JØ (2016) 'Small-scale land acquisitions, large-scale implications: exploring the case of Chinese banana investments in Northern Laos', *Land Use Policy,* 57:117–129.

Hall D (2011) 'Land grabs, land control, and Southeast Asian crop booms', *Journal of Peasant Studies,* 38:837–857.

Hansen KP, Sodarak H and Savathvong S (1997) *Teak production by shifting cultivators in Northern Lao P.D.R.*, Technical Report No. 9, Shifting Cultivation Research Sub-programme, Lao Swedish Forestry Programme, Luang Prabang, Laos.

Hayward D, Lwin UK, Bin Y and Kyu UH (2020) *Chinese Investment into tissue-culture banana plantations in Kachin State, Myanmar*, Case Study Series #4, Mekong Region Land Governance, Vientiane, Yangon.

Hermans TDG, Whitfield S, Dougill AJ and Thierfelder C (2021) 'Why we should rethink "adoption" in agricultural innovation: empirical insights from Malawi', *Land Degradation & Development,* 32:1809–1820.

Hirsch P and Scurrah N (2015) *The political economy of land governance in Lao PDR*, Mekong Region Land Governance, Vientiane, Laos.

Irawanti S, Ginoga KL, Prawestisuka A and Race D (2014) 'Commercialising community forestry in Indonesia: lessons about the barriers and opportunities in Central Java', *Small-scale Forestry,* 13:515–526.

Jagger P and Pender J (2003) 'The role of trees for sustainable management of less-favored lands: the case of eucalyptus in Ethiopia', *Forest Policy and Economics*, 5:83–95.

Junquera V, Meyfroidt P, Sun Z, Latthachack P and Grêt-Regamey A (2020) 'From global drivers to local land-use change: understanding the northern Laos rubber boom', *Environmental Science and Policy,* 109:103–115.

Kallio MH, Hogarth NJ, Moeliono M, Brockhaus M, Cole R, Waty Bong I and Wong GY (2019) 'The colour of maize: visions of green growth and farmers perceptions in northern Laos', *Land Use Policy,* 80:185–194.

Kenney-Lazar M (2012) 'Plantation rubber, land grabbing and social-property transformation in southern Laos', *The Journal of Peasant Studies,* 39:1017–1037.

Khasanah NM, Perdana A, Rahmanullah A, Manurung G, Roshetko JM and Van Noordwijk M (2015) 'Intercropping teak (*Tectona grandis*) and maize (*Zea mays*): bioeconomic trade-off analysis of agroforestry management practices in Gunungkidul, West Java', *Agroforestry Systems,* 89:1019–1033.

Lienhard P, Castella J-C, Ferrand P, Cournarie M, D'aquino P, Scopel É and Bougnoux N (2019) 'Accompanying the actors of the agroecological transition in Laos', in Côte F-X, Poirier-Magona E, Perret S, Rapidel B, Roudier P and Thirion M-C (eds) *The agroecological transition of agricultural systems in the Global South*, *Éditions* Quae, Versailles, France.

Ling S, Smith H, Xaysavongsa L and Laity R (2018) 'The evolution of certified teak grower groups in Luang Prabang, Lao PDR: an action research approach', *Small-scale Forestry,* 17:343–360.

Lu J (2017) 'Tapping into rubber: China's opium replacement program and rubber production in Laos', *The Journal of Peasant Studies,* 44:726–747.

Lu J and Smith HF (2023) 'From booms to bans: governing land and forests in Laos', *Sociology of Development, 9*(2):131–150.

Maraseni TN, Phimmavong S, Keenan RJ, Vongkhamsao V, Cockfield G and Smith H (2018) 'Financial returns for different actors in a teak timber value chain in Paklay District, Lao PDR', *Land Use Policy,* 75:145–154.

McCarthy JF (2019) 'The paradox of progressing sideways: food poverty and livelihood change in the rice lands of outer island Indonesia', *The Journal of Peasant Studies,* 47:1–21.

Meijer SS, Catacutan D, Ajayi OC, Sileshi GW and Nieuwenhuis M (2015) 'The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa', *International Journal of Agricultural Sustainability,* 13:40–54.

Midgley S, Blyth M, Mounlamai K, Midgley D and Brown A (2007) *Towards improving profitability of teak in integrated smallholder farming systems in northern Laos*, ACIAR Technical Report No. 64, Australian Centre for International Agricultural Research, Canberra, Australia.

Midgley S, Mounlamai K, Flanagan A and Phengsopha K (2015) *Global markets for plantation teak; implications for growers in Lao PDR,* a report for ACIAR project FST/2010/012, Australian Centre for International Agricultural Research, Canberra, Australia.

Molnar TJ, Kahn PC, Ford TM, Funk CJ and Funk CR (2013) 'Tree crops, a permanent agriculture: Concepts from the past for a sustainable future', *Resources*, 2:457–488.

MPI (Ministry of Planning and Investment) (2021) *The 9th five-year national socio-economic development plan (2021-2025)*, Committee for Planning and Investment, MPI, Vientiane, Laos.

Nair C and Souvannavong O (2000) 'Emerging research issues in the management of teak', *Unasylva*, 201:45–54.

Narh P (2019) 'Sustainability outcomes of teak plantation development in Dormaa, Ghana', *Environmental Development,* 29:44–54.

Newby J, Cramb R and Sakanphet S (2014) 'Forest transitions and rural livelihoods: multiple pathways of smallholder teak expansion in Northern Laos', *Land,* 3:482–503.

Newby J, Cramb R, Sakanphet S and McNamara S (2012) 'Smallholder teak and agrarian change in northern Laos', *Small-scale Forestry,* 11:27–46.

Nuberg IK, Shrestha KK and Bartlett AG (2019) ‘Pathways to forest wealth in Nepal’, *Australian Forestry,* 82:106–120.

Pachas ANA, Sakanphet S, Midgley S and Dieters M (2019) ‘Teak (*Tectona grandis*) silviculture and research: applications for smallholders in Lao PDR’, *Australian Forestry,* 82:94–105.

Pannell DJ, Marshall GR, Barr N, Curtis A, Vanclay F and Wilkinson R (2006) ‘Understanding and promoting adoption of conservation practices by rural landholders’, *Australian Journal of Experimental Agriculture,* 46:1407–1424.

Perz SG and Walker RT (2002) ‘Household life cycles and secondary forest cover among small farm colonists in the Amazon’, *World Development,* 30**:**1009–1027.

Phengsopha K (2015) ‘How Lao forest industry is managed? loopholes in governance and in practice’, *International Journal of Business and Social Science*, 6(11).

Phimmavong S, Ozarska B, Midgley S and Keenan R (2009) ‘Forest and plantation development in Laos: history, development and impact for rural communities’, *International Forestry Review,* 11:501–513.

Pousajja R (1996) *Eucalyptus plantations in Thailand*, report submitted to the regional expert consultation on eucalyptus, Food and Agriculture Organization of the United Nations, Bangkok.

Puntasen A, Siriprachai S And Punyasavatsut C (1992) ‘Political economy of eucalyptus: business, bureaucracy and the Thai government’, *Journal of Contemporary Asia,* 22:187–206.

Race D and Wettenhall G (eds) (2016) *Adding value to the farmers’ trees: experiences of community-based commercial forestry in Indonesia*, Australian Centre for International Agricultural Research, Canberra, Australia.

Rigg J (2005) *Living with transition in Laos: market Integration in Southeast Asia* (1st ed.), Routledge.

—— (2006) ‘Land, farming, livelihoods, and poverty: rethinking the links in the Rural South’, *World Development*, 34:180–202.

—— (2020) *Rural development in Southeast Asia: dispossession, accumulation and persistence*, Cambridge University Press.

Rigg J, Phongsiri M, Promphakping B, Salamanca A and Sripun M (2020) ‘Who will tend the farm? interrogating the ageing Asian farmer’, *The Journal of Peasant Studies,* 47:306–325.

Roder W, Keoboualapha B and Manivanh V (1995) ‘Teak (*Tectona grandis*), fruit trees and other perennials used by hill farmers of northern Laos’, *Agroforestry Systems,* 29:47–60.

Roshetko J, Rohadi D, Perdana A, Sabastian G, Nuryartono N, Pramono AA, Widyani N, Manalu P, Fauzi MA, Sumardamto P and Kusumowardhani N (2013) ‘Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation’, *Forests Trees and Livelihoods,* 22:241–256.

Santasombat Y (2019) ‘Rent capitalism and shifting plantations in the Mekong Borderlands’, *Southeast Asian Affairs,* 2019:177–191.

Scott J (1998) *Seeing like a state: how certain schemes to improve the human condition have failed*, Yale University Press, New Haven, CT.

Sikor T (2012) ‘Tree plantations, politics of possession and the absence of land grabs in Vietnam’, *The Journal of Peasant Studies,* 39:1077–1101.

Sikor T and Baggio JA (2014) ‘Can smallholders engage in tree plantations? an entitlements analysis from Vietnam’, *World Development,* 64:S101–S112.

Smith D, Newby J and Cramb RA (2018a) *Developing value-chain linkages to improve smallholder cassava production in Southeast Asia*, Cassava program discussion paper number 3, ISSN 2209-2684, School of Agriculture and Food Sciences, University of Queensland, Australia.

Smith HF (2021) *Rethinking the role of traders, micro, small and medium enterprises in efficient plantation-wood markets: insights from Laos*, report produced for ACIAR project FST/2016/151 ’Advancing enhanced engineered wood products in Lao PDR and Australia’, Australian Centre for International Agricultural Research, Canberra, Australia.

—— (2022) *A snapshot of plantations in Lao PDR*, info brief compiled for ACIAR project FST/2016/151 ’Advancing enhanced engineered wood products in Lao PDR and Australia’, VALTIP3 and the Centre for Development and Environment under the Knowledge for Development (K4D) project.

Smith HF, Barney K, Byron N, Van Der Meer Simo A, Phimmavong S, Keenan R and Vongkhamsao V (2017a) *Tree plantations in Lao PDR: policy framework and review*, Project Working Paper 1, Australian Centre for International Agricultural Research, Canberra, Australia.

Smith HF, Ling S, Barney K and Kanowski P (2018b) *Value chain assessment: interim summary report – Teak plantations in Northern Laos*, [technical report], Australian Centre for International Agricultural Research, Canberra, Australia.

Smith HF, Ling S and Boer K (2017b) 'Teak plantation smallholders in Lao PDR: what influences compliance with plantation regulations?', *Australian Forestry,* 80**:**178–187.

Smith HF, Lu J, To PX, Mienmany S and Soukphaxay K (2020) *Rubber Plantation value chains in Laos: opportunities and constraints in policy, legality and wood processing*, report for ACIAR project FST/2016/151, Australian Centre for International Agricultural Research, Canberra, Australia.

Smith HF, Riddy C and Carmichael E (2022) *Emerging forest governance regimes and implications for the small-scale plantation sector in Lao PDR*, Key findings from three ACIAR-funded projects in Lao PDR, Research info brief, ACIAR projects FST/2016/151, ADP/2014/147 and FST/2019/121, Australian Centre for International Agricultural Research, Canberra, Australia.

Sylvester (2018) *Towards responsible agricultural investment in Lao PDR: a study of agribusiness experiences*, GIZ (Deutsche Gesellschaftfür Internationale Zusammenarbeit).

Szulecka J, Pretzsch J and Secco L (2014) 'Paradigms in tropical forest plantations: a critical reflection on historical shifts in plantation approaches', *International Forestry Review,* 16:128–143.

Van Der Meer Simo A, Kanowski P and Barney K (2020) 'The role of agroforestry in swidden transitions: a case study in the context of customary land tenure in Central Lao PDR', *Agroforestry Systems,* 94:1929–1944.

Versteeg S, Hansen CP and Pouliot M (2017) 'Factors influencing smallholder commercial tree planting in Isabel Province, the Solomon Islands', *Agroforestry Systems,* 91:375–392.

Vongkhamchanh P and Van Der Heide J (1989) *Tropical forest action plan*, Discussion paper on land use in forestry, IUCN, Laos.

Vongvisouk T and Dwyer M (2017) *After the boom: responding to falling rubber prices in Northern Laos*, Thematic Study Series #4: Mekong Region Land Governance and Forest Trends, Vientiane, Laos.

Chapter 5

Reversing massive deforestation in Vietnam and Costa Rica

Duc Minh Lo, Ken Gallatin and J Doland Nichols

Abstract

Vietnam and Costa Rica are both tropical countries that have undergone massive deforestation and human population growth since the middle of the 20th century. Various approaches have been taken to encourage small farmers to establish tree cover on their farms for both environmental and commercial purposes. In Costa Rica during the 1980s, an international program provided incentives to farmers to plant a variety of mainly exotic tree species on their farms, with varying success. In Vietnam, since the late 1980s there has been a general movement away from government management of forests to community forestry and private plantations on small farms. As part of this push, more than 2 million hectares of Australian *Acacia* species have been planted for short-term production of woodchips and small sawlogs.

Several efforts have been made to explore the possibility of domestication of some of the many highly valuable native rainforest trees in both countries, but with limited success. We briefly explore here both the biophysical and the socioeconomic policy challenges to encouraging viable on-farm forestry in these 2 countries and offer suggestions on how successful smallholder forestry could be developed.

Introduction

Vietnam and Costa Rica are both tropical countries, although Costa Rica has a population of only about 5 million people, whereas Vietnam's population is rapidly approaching 100 million. Both countries are well known for their rich biodiversity, which has greatly diminished since the 20th century. Both countries have also gone through transitions in terms of the roles of markets and governments in regulating land use, as well as in other aspects of society. Governments, individuals and non-government organisations have implemented an astounding array of forestry programs and there have been myriad changes in policy over the years. It would be too lengthy to describe all of these programs here,[11] so instead we summarise salient points about what has happened, particularly in terms of successful farm forestry, and the foundation that has been laid for smallholder forestry.

Forests play an important role in helping us adapt to climate change through environmental functions such as preventing erosion and ensuring water circulation, and slowing down the advance of global warming (Do et al. 2018). Forests play a vital socioeconomic role, contributing to job and income generation. In Vietnam in recent years, the forest area has recovered rapidly with a recent estimate of forest area being 14.7 million ha and covering 42% of the country (MARD 2021). For its part, Costa Rica also has recovered much of its forest area, from a low of 21% of the country to about 52% today (Rodriguez 2022). This is not to say that the primary (natural) forests that were cleared in the 20th century are now back as primary forests – rather, those reforested lands now consist of a complex array of plantations and young secondary forests.

History of forestry in Vietnam

Reforestation is 'regreening' bare land, creating jobs, and improving the living standards of people living in the mountainous areas of Vietnam. This is the result of several programs that supported large-scale afforestation and industrial wood production. Government policies and regulations have also laid a solid foundation for the development of afforestation areas and the conservation of forest ecosystems, although in recent years forests and forest land have been allocated and contracted to organisations, institutions, households and individuals. Consequently, forest use has been driven by both environmental and commercial factors in Vietnam (Luong 2014).

Forest is classified into 3 major categories in Vietnam:

- **Protection** forests are used to protect water sources and soil, prevent erosion, combat desertification, limit natural disasters, regulate climate and protect the environment overall. Often, what are woodlots of single species, especially pines and teak, are classified as protection forests and are off limits for timber harvesting (McElwee 2016).
- **Special-use** forests are mainly used for conserving nature, including forest biological genetic resources; scientific research; protecting historical, cultural relics and scenic spots; and for recreational areas and tourism, combined with environmental protection and production forest.
- **Production** forests are used to grow trees for the commercial sale of timber or other forest products. Households and businesses can lease plantation forests for intercropping with agriculture crops; harvesting non-timber forest products; grazing livestock; aquaculture; and harvesting timber for construction works serving ecotourism.

11 For examples, see the World Bank's 151-page report on Costa Rica (de Camino et al. 2000) and McElwee's 283-page report on Vietnam (2016).

Each category may include natural forests, secondary forests, restoration forests and logged forests. Natural forests include those that have regenerated naturally, without human aid, and primeval forests, which are largely untouched by humans. After many decades of catastrophic losses, what natural forests remain are protected to some extent in national parks. Secondary forests are forests affected by humans or natural disasters to the extent that the forest structure has been altered. Restoration forests are those formed by natural regeneration on land that has been deforested by humans, through shifting cultivation, forest fires, logging and, in Vietnam, the effects of war, including the spraying of the herbicide Agent Orange.

The French influence

In Vietnam's feudal era, forests were a resource owned by the dynasties; only the king had the right to manage and exploit the forest. To the people, the forest was a gift from heaven. Vietnam's forests were widespread and provided a rich abundance of forest products. With a small population and low demand, the forest area exploited had a relatively small effect on the environment and people's lives. In 1858, France attacked Da Nang, the beginning of the invasion of Vietnam. To monopolise the exploitation of forest resources, the French enforced policies and regulations that gave them sole rights to manage, tax and use forests throughout Vietnam and Indochina. Forestry policies and regulations implemented by the French included establishing an area for permanent forests, after first determining which areas were with and without forest. They attempted to ensure that supply met the demand for timber and forest products, while setting aside some forests to protect the landscape and as government reserve forests.

Afforestation zones were set up in districts where forests were considered of poor quality or where the hills were "bare" (Lamb 2010). As part of this process, several plantation forests of specific native and imported tree species were established, such as Masson pine (*Pinus massoniana*) and teak (*Tectona grandis*) (MAR 2004; McElwee 2016).

Democracy, war and a growing population

During the period 1930 to 1941, forestry development and afforestation were under the authority of the French colonial state. After the State of the Democratic Republic of Vietnam came to power in 1945, the government established the Ministry of Agriculture, with the task of preventing deforestation and preserving forests. Afforestation took place on remote hills and on land that could not be used for agriculture. During the 2 decades of war from 1955 to 1975, demand for wood was high and forests were heavily affected, particularly in the North Central Coast Region. Many exotic tree species and planting techniques were established in this period, using *Eucalyptus exserta, E. robusta, E. tereticornis,* and *Populus* species. Since the American war ended in 1975, the area of planted forest has increased every year. Although afforestation is planned, it is mainly done for 'greening' purposes, meaning some plantations are not to be used for wood, even though they are of timber species.

With the launch of the Đổi Mới policy in 1986, Vietnam's forest area decreased by several million hectares for many reasons. The government did not have clear regulations pertaining to use of forested land and forest area data was lacking. The pressure of population growth increased the need to reclaim land, resulting in the conversion of a large area of forest into agricultural land (Minh et al. 2011).

From 1991 to 1997, there was a strong renewal and expansion of international relations, as well as pressures due to demand for forest products, environmental protection and flood prevention. Combined, these pressures increased attention on afforestation and forest restoration. Many technological advances and new perspectives on afforestation were introduced. Since 1993, in particular, when Programme 327 was launched to re-green uplands, the government has invested in in afforestation, forest protection and special-use forests. Over the 4 years to 1997, the government invested about US$94 million (2,287 billion Vietnamese dong) to protect 1.6 million ha of forest; regenerate 409,000 ha; and plant 543,000 ha of new forest comprising 83,600 ha of timber trees and 39,800 ha of fruit trees.

Several program limitations were exposed in the process. It was unclear which lands would be planted and for what purposes. Allocation of land and forest contracts did not comply with protection planning and the provisions of the law, leading to people feeling insecure about what was legal and what was not. Inflexible government support policies on aspects such as tree density, the kind of crops and unit cost of investment made the program difficult for project officers and member households to implement. The capital management mechanism has not been fully understood in villages and is especially difficult to implement in ethnic communities. Planting of protective forests required using native trees, but many varieties had yet to be tested. Consequently, afforestation was not done in accordance with approved technical processes, resulting stands were of poor quality and, often, species were mismatched to sites where they were planted.

The 5-million-hectare reforestation program of 1998

In 1998, Decision 661 was intended to make a significant contribution to bringing the total forest coverage to over 40% of the country's land area. It became known as the 5-million ha reforestation project and had 3 main objectives:

- Promote afforestation and greening on bare land and bare hills.
- Focus on protecting existing forest and planting new forests.
- Promote biodiversity.

Also, it was intended to create substantial areas to support the development of the forest product processing industry. Further objectives were to create more jobs, increase income for the population, and contribute to the implementation of the policy aimed at eradicating hunger and reducing poverty.

The 5-million-ha reforestation project became a key economic-socio-ecological program of Vietnam. By 2010, there were 944 projects in place, including 655 projects on afforestation for protection and special-use forests, plus 289 projects to support production forests. The government issued detailed plans to plant 2 million ha of protection forests and special-use forests, and 3 million ha of production forests. Between 1998 and 2005, 723 'grassroots' forestry projects were implemented throughout Vietnam.

This project has accelerated the speed of forest restoration, created new forests, increased forest cover and contributed to socioeconomic development in mountainous areas where ethnic minorities live. The project also contributes significantly to creating jobs, reducing the number of poor households. It has deepened and broadened the population's awareness of tree planting, afforestation and forest protection and their role in the economic, social and environmental spheres. It has drawn attention to research and investment in forestry, and facilitated the rapid introduction of technical advances into production.

Planting native-species or mixed-species plantations for protected forest and special-use forests was encouraged by various government agencies (Lamb 2010). Previously, such plantations would not have attracted resources from co-investing companies because they require large budgets and have long business cycles, high risks, low productivity and low efficiency. Investment capital for afforestation is low and loans are limited, with interest rates still high. Loans are not allowed in advance to prepare seedlings and materials, ensuring a timely planting.

In Vietnam, agroforestry systems have shown promise as sustainable farming systems on sloping land. Agroforestry is known in Vietnam as the Garden/Fishpond/Livestock model, which was intensively developed and promoted throughout the country (Nguyen et al. 2022). In 1980, the government established a new economic zone and long-term population redistribution program (Decision 95/CP) aimed at encouraging lowland people to migrate to the Central Highlands and northern mountain regions. As a result, the population in mountainous areas of the north increased rapidly. The migrants brought with them agricultural practices from the lowland and the traditional Garden/Fishpond/Livestock model was modified to a Forest/Garden/Fishpond/Livestock model, which was more suited to hilly areas (Hoa and Catacutan 2012). ACIAR has also long supported agroforestry research projects in Vietnam (ACIAR 2021, 2022).

The government's cooperative forestry development projects support farmers by providing free seedlings, yet the choice of species and fertiliser use has, in reality, often been selected by project managers, with little consultation with local people. Consequently, people do not fully understand and know about the species planted on their land. Local people's participation in tree planting could be more effective if people were organised into supported groups. The groups could then offer technical assistance and represent individuals when proposing changes in forest planning or management. Such handing over to the community of forest management to benefit them – non-timber product benefits, spiritual benefits, timber products for home repair – would truly represent the concept of community forestry.

Figure 5-1: An acacia plantation in the Huong River watershed, Vietnam

Credit: Rodney Keenan

The success of acacia plantings in Vietnam

Byron (2001) distinguished 4 frequently referenced keys to success for smallholder forestry (Midgley et al. 2017):

- clear ownership of trees
- reliable markets
- sympathetic legal and regulatory frameworks
- a robust package of technical options.

Quite commonly, one or more of these conditions is missing, making the likelihood for success extremely low. An example is the case of farmers who are growing native rainforest species, which have value as large native forest logs, but for which no viable market exists for their small-diameter farm-grown trees in the short term; then they face a difficult framework of confusing legislation and policies that discourages tree harvesting.

Approximately half of the forest plantation estate in Vietnam is managed by smallholders, with 80% going to woodchip. Exact numbers are hard to obtain, but there are at least 2 million hectares of acacia plantations in the country, for the most part a hybrid of 2 species, *A. mangium* x *A. auriculiformis* (Le and Ha 2017).

One objective of forestry sector workers has been to promote silviculture of acacia to produce sawlogs rather than woodchips, holding on to trees for 8 to 10 years, rather than ending a rotation after 5 years. Tham et al. (2021) have written about developing the potential of small acacia logs. As an example, a contractor near Hue in central Vietnam makes garden furniture for IKEA from small logs from acacia plantations (Nguyen et al. 2018).

Figure 5-2: Acacia logs grown for furniture rather than woodchips, Vietnam
Credit: Rodney Keenan

In addition to the millions of hectares in officially counted plantations, smallholdings are a 'hidden asset' in parts of Asia, according to Midgley et al. (2017). They estimated that the equivalent of more than 600,000 ha of unaccounted acacia smallholdings and informal plantings produce more than 9 million cubic metres of wood (for export as woodchips) with a value of more than US$500 million.

Although most tropical tree plantations are of a few common species – pines, eucalypts, acacias and teak – over the last few decades there has been increasing interest in the use of native species. Since hundreds of species are typically found in rainforests, many of which are commercially desirable, this growing interest creates a need for research into how to 'domesticate' them. Issues for research include understanding fruiting and seeding phenology, developing nursery techniques, and learning how to manage new native species on farms and in plantations.

Native species in Vietnam

There are many native rainforest species that could be domesticated in Vietnam (Crowther 2020). In coastal areas, as we have stated, growing *Acacia* species on short rotations for woodchips, or on slightly longer rotations for small sawlogs, can be financially viable for smallholders. While a few attempts have been made to domesticate native species, the general impression seems to be that their growth rate is 'too slow' (Dong et al. 2014; Nguyen et al. 2014; Nguyen et al. 2018). Dong et al. examined some of the eco-physiological limitations of growing the many native species of the Dipterocarpaceae family. Nguyen et al. (2014) compared the profitability of *Canarium album*, one of the natives most often promoted, to *Acacia mangium,* which yielded more profit within a shorter period of time.

In the ACIAR project, 'Developing and promoting market-based agroforestry and forest rehabilitation options for northwest Vietnam' (FST/2016/152), villagers in the NaBai and NaNoi communities were supported in planting native species *Cunninghamia lanceolata* (sa mộc), *Manglietia mediocris* (giổi xanh), *Canarium tramdenum* (trám đen) and *Manglietia conifer* (mỡ). This work was continued under the 'Vietnamese native tree species for improved livelihoods' project (FST/2020/134). Joint activities were undertaken in community forest areas, such as enrichment planting, planting of non-timber-forest-product species and assisting natural regeneration in steep patches of previously exploited native forest. Households in these villages registered to grow trees on their family's forest area, ensuring that some follow-up will occur. Another activity involved establishing forest protection teams – consisting of members of the youth union, women's union and veterans' union, as elected by village people – who patrol monthly, monitoring and detecting abnormal activities during their fieldwork. Based on interviews with project participants, the most common responses about what people gained from the project were 'planting and care for forest trees', 'care for the community's landscape', 'land and soil care techniques' and 'farm and landscape designing from agroforestry system model'. Also, participants thought that the project time should be extended because the forest trees need a long period before delivering income for growers. They would like further help to find stable markets, particularly for the non-timber forest products. Finding short-term income products from these products could prove a solution in encouraging farmers to plant native trees.

Over the last 50 years, many research projects have examined the propagation and growth of native tree species in both Vietnam and Costa Rica and, at the very least, developed our knowledge, indicating that many species have value. However, we believe that no native species has yet emerged that can be managed profitably by smallholders for timber. This is not to say that practices will not evolve, particularly as demand for wood, especially of high-value timbers, increases.

Recent history of forestry in Costa Rica

Since at least the 1980s, there has been systematic interest in planting native tree species, starting with research projects designed to identify priority species, and to understand how to propagate them in nurseries and how to grow them in plantations (Nichols and Gonzalez 1992; Gonzalez and Fisher 1994; Solis and Moya 2004). Species such as amarillon (*Terminalia amazonia*) are well known from native forests across a wide range, from Mexico to Brazil and the Caribbean. It takes decades to develop seed collection protocols, nursery protocols, and technologies for processing farm-grown smaller trees (Nichols 1994; Soliz and Moya 2004; Sinacore et al. 2022). Therefore, if a viable culture is to develop around native species, it is critical that germplasm from native forest is preserved before it all disappears.

Gmelina arborea

Gmelina (*Gmelina arborea*) is a fast-growing tropical tree species, in the same family (Verbenaceae) as teak (*Tectona grandis*). In the late 1980s, a company called Ston Forestal, a subsidiary of the large international company Stone Container Corporation, established large areas of gmelina in south-western Costa Rica. They paid landholders to lease land and establish their plantations for the purpose of producing trees that could be converted to woodchips and then shipped to pulp mills in the USA for paper production. They succeeded in establishing about 25,000 ha of gmelina in this region (Ewing 2017).

The trees were never harvested by the company because agreements between government agencies and Ston Forestal to build port facilities and a chip mill fell apart. Eventually, landholders realised that they were free to do as they wished, particularly after Ston Forestal ceased making lease payments.

When small gmelina trees are harvested, at about 14 years of age, they can be used for a variety of purposes. Landholders found they could use the bottom log for furniture and plywood production, wood from the middle of the stem suited construction timbers, and the smallest logs could be processed for boxes, pallets and log cabins (Roque 2004). Once the wide product range of gmelina timber was realised, combined with the relatively concentrated 25,000-ha resource in south-western Costa Rica, gmelina became a favoured, in-demand species (Ewing 2017).

Incentives for smallholder forestry in Costa Rica

Forestry incentives in Costa Rica can be invaluable for getting farmers and other landowners to plant and manage timber species, but it is crucial that such programs are well regulated and that technical assistance is easily available for the planting process and for later management. Many farmers take advantage of forestry incentives principally for the short-term economic benefits offered – they may not see the logic in waiting for decades for a return on their investment, nor be very interested in producing timber. Regulations need to be in place and enforced to ensure that people who take advantage of forestry incentives plant the trees and correctly manage them. Even when farmers are motivated by the idea of planting trees and one day seeing timber produced from those trees for the benefit of their families, there has to be timely technical silvicultural assistance so that they can produce quality timber in a reasonable time frame. Past forestry incentive programs in Costa Rica for farmers have lacked both regulation enforcement and technical assistance, leading to a failure, in large part, in the production of timber from the incentivised plantings or, at the very least, failure in the production of important volumes of quality timber.

In the late 1980s through the mid-1990s, various programs in Costa Rica tried to incentivise the creation of timber plantations, both through direct cash payments and tax breaks. Those that had the biggest impacts in motivating smallholder farmers were the *Certificado de Abono Forestal* program and the *Fondo de Desarollo Forestal* program. Each program offered cash payments for every hectare planted in timber species, spread out over the first several years of a plantation's life. The main difference between them was that the *Certificado de Abono Forestal* program demanded that the beneficiary of the payments have legal title to their land while the *Fondo de Desarollo Forestal* program did not. Both programs suffered from a lack of regulation enforcement and technical assistance.

To illustrate this point, I (co-author Ken Gallatin) was the forestry extensionist for the *Fondo de Desarollo Forestal* program of the Peninsula de Osa sector of Costa Rica in 1991 and 1992, and personally experienced the deficiencies of that program. I was the only trained technical officer / regulator for more than 200 farmers spread out over the largely roadless 1,740-square-kilometre peninsula, and my job was for only one week per month. Travelling to the various small farms on foot and horseback was arduous and meant I was able to visit only a handful of farmers each month, which led to them lacking supervision and technical advice. Some examples of what I at times found on arriving at a farmer's plot, tucked away in the jungle:

- They were planting their trees in the understorey of the forest instead of on open terrain as prescribed, perhaps not to lose productive agricultural land.
- They had outplanted the seedlings in a recently abandoned field in a proper area, but the seedlings were never cleaned, and were left to suffer under weeds and vines.
- They had planted no trees at all.

Of course, some farmers created their nurseries, prepared appropriate terrain, outplanted their seedlings and kept them mainly clear of competing vegetation, but many did not. I would explain to them what steps they needed to take to correct the mistakes and try to convince them to follow through on said steps – some made an effort and some did not. I dutifully reported what I found in the field to the institution that was managing the program at the local level, the *Centro Agrícola Cantonal*, and suggested to them which farmers had done an adequate job and should receive their incentive cheques on time and which ones should be delayed until they corrected deficiencies. Regardless of my reports and suggestions, all farmers in the program always received their full payments on time. The *Centro Agrícola's* chief interest was in maximising the flow of funds, of which they received a percentage.

Both *Certificado de Abono Forestal* and *Fondo de Desarollo Forestal* programs ended in 1995 and paying cash incentives to farmers for establishing and maintaining small plantations has not been attempted by the government since. Other incentives have been, and are still being, offered, but have less appeal to smallholder farmers. For example, where a plantation is created with the landowner's resources, they receive a deduction on property taxes and taxes on any assets used in the creation and maintenance of the plantation; exemption from income taxes on profits generated by the plantation; and protection against any squatters that might try to move onto their plantations. Costa Rican law also states that land containing timber plantations, and even the individual trees on said land, are suitable for use as guarantees for mortgages and other types of loans; however, in my experience banks use the excuse that it's impossible to calculate the actual value of a tree or stand of trees for not granting loans based on guarantees of tree value. These incentives are not very attractive to most farmers since family farms are small, the profits are meagre, and they pay very little property tax and little to no income tax. They want to see some money quickly from any venture and are not generally motivated by a tax exemption on any timber profits many years in the future. Neither are squatters a problem on land where the farmers live and work every day.

What kind of incentives work best for smallholder farmers in Costa Rica? You can offer free trees and they may take some and plant them around the house and farm, and they may or may not take care of them, which may be fine if the goal is to have scattered trees planted on farms. The more intangible incentives, such as tax breaks, which are the current incentives for timber plantations in Costa Rica, are more geared towards large landowners and businesspeople, not smallholder farmers. These farmers are trying to get through the year or month or week and like to see cash coming in quickly from what they do, preferably yesterday. If you want to get a farmer's attention, offer cash for planting and maintaining trees. Once you have their attention, we recommend following through with good technical assistance and inspections to assure that the trees are actually planted and maintained.

To make any tree planting incentive program work, it is vital that the people working in the field with the farmers are motivated to make the program a success, and can empathise and communicate clearly with the farmer. On top of that, the administration of the program needs to be minimal and clean – minimal so that the farmer understands and carries out the work needed; clean so that graft is kept at bay and as much of the funding as possible is spent on getting trees into the ground. Powlen and Jones (2019) concluded after extensive interviews in Costa Rica that landholders are unlikely to participate in reforestation given their lack of technical skills for planting trees, unsuccessful past experiences, their lack of trust in external organisations and the prohibitive initial costs of planting.

Figure 5-3: **The landscape in NaBai village, near Van Ho, northwest Vietnam. Several projects supported by ACIAR research have promoted systems using trees in agroforestry combinations. Dozens of projects have tried to solve the problems associated with living, growing crops and grazing livestock on such extreme slopes.**

Increasing forest cover: but what kind?

In Vietnam, forest cover increased from a low point of 9.4 million ha in 1990 to 14.6 million ha in 2020 (McElwee and Nghi 2021). By some estimates, Costa Rica's forest cover increased from 21% in 1940 to 52% in 2010 (Rodriguez 2022), although much of this may be cleared within a few decades (Perez-Ortega 2018). Both Costa Rica (Rodriguez 2022) and Vietnam (Truong et al. 2017) claim to have gone through 'forest transitions' in which new forests are reclaiming deforested lands.

Forest cover may indeed be increasing in both countries, but what kind of forest is it? Is it one that benefits the environment because it occurs naturally or contains native pioneer species that are being nurtured to become the forest's primary species? Some authors (McEwee 2016) see little value in plantations of exotic species and in many ways do not consider them as reforestation, arguing that the resulting landscape is a monocultural 'desert.'

Much of the new forest cover in Costa Rica (Figure 5-4) can be categorised as naturally occurring secondary forest. Some sources (Rodriguez 2022) consider this a wonderful success story of forest reclaiming the land, whereas others (Perez-Ortega 2018) argue that most of these secondary forests do not have a long-term future and are in effect in a 'fallow' state, and, in general, are destined for clear-fall within one or 2 decades.

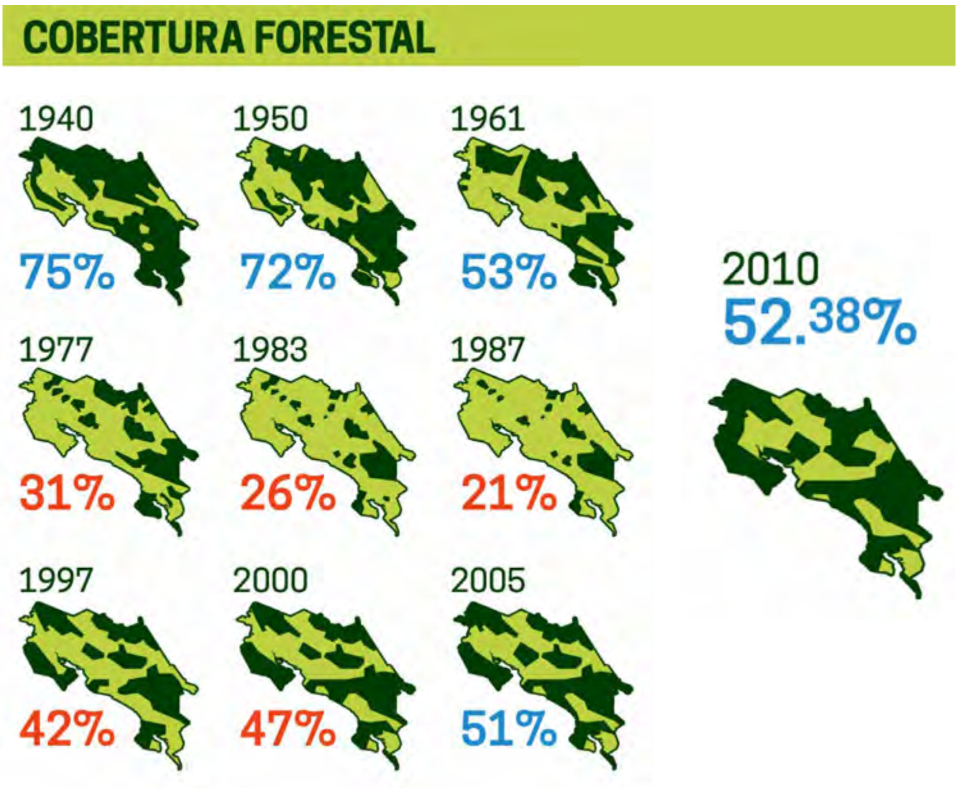

Figure 5-4: Changes in forest cover, Costa Rica, 1940–2010

Source: *Revista Vacío* (http://revistavacio.com/ciencia-y-tecnologia/costa-rica-pais-verde)

Recommendations for developing smallholder forestry

- Primary forests are disappearing rapidly, so collect seed of desirable species while the mother trees still exist.
- To develop a viable economy, create a critical mass of wood that can be processed.
- Be open to plan Bs and plan Cs – the original intended use may turn out not to be the actual use, as needs and economies change. A prime example is the emergence of *Gmelina arborea* as a desirable, fast-growing producer of solid wood, in comparison to its original destiny as woodchips.
- Develop and transmit silvicultural knowledge for the hundreds of valuable rainforest species about which little is known. This is an ongoing and vast need.
- Focus on tree species/systems that will function on more difficult, degraded or less accessible sites. Conveniently located fertile land is probably better used for generating income from annual or cash crops.
- Consider whether tree species with which people are familiar, and appreciate, are easier to promote than unknown native or exotic species.
- Simply giving trees away is often a bad idea. The short-term nature of many programs supporting smallholder forestry often leads to abandonment of planted seedlings. Choose long-term programs and provide clear methods for following up on the tending and monitoring of trees planted.

Conclusions

Both Vietnam and Costa Rica have success stories, of sorts, with large-scale monocultural plantations providing a financially viable land use for some farmers – 2 million ha of *Acacia* (mainly hybrids) in Vietnam and about 25,000 ha of *Gmelina arborea* in south-west Costa Rica.

In both countries, an untapped wealth of tropical tree species exists along a wide altitudinal range and in environments with varying soils and climates. To date, no widespread use of native species, in either pure or mixed plantations, has become a part of the landscape – at least not yet. In both Costa Rica and Vietnam, maturing secondary forests of native species could be harnessed and protected, then the 'forest transition' might prove a real gain. Furthermore, if the gradual accumulation of knowledge about the best silviculture for each native species could be shared and applied on progressively larger scales, then viable forestry and agroforestry on small farms could eventually be achieved. And if government programs, such as the billion trees initiative in Vietnam (Tatarski 2021) could be well managed, they too could become a step in the right direction. For this to happen, it is vital that the efforts to date of so many scientists, foresters and farmers are supported and persist long into the future.

References

ACIAR (1 October 2021) *Ten years of agroforestry projects in northwest Vietnam*, ACIAR website, Australian Centre for International Agricultural Research, Canberra, Australia, accessed 15 September 2023.

Byron RN (2001) 'Keys to small-holder forestry', *Forests, Trees and Livelihoods*, 11:279–294.

Crowther J, Zimmer H, Le Thi H, Quang TL and Nichols JD (2020) 'Forestry in Vietnam: the potential role for native timber species', *Forest Policy and Economics*, 116(April):102182, doi:10.1016/j.forpol.2020.102182.

de Camino R, Segura O, Arias LG and Pérez I (2000) *Costa Rica: Forest strategy and the evolution of land use*, World Bank, Washington, D.C.

Do TH, Vu TP, Nguyen VT and Catacutan D (2018) 'Payment for forest environmental services in Vietnam: An analysis of buyers' perspectives and willingness', *Ecosystem Services*, 32(July):134–143, doi:10.1016/j.ecoser.2018.07.005.

Dong TL, Beadle CL, Doyle R and Worledge D (2014) 'Site conditions for regeneration of *Hopea odorata* in natural evergreen dipterocarp forest in southern Vietnam', *Journal of Tropical Forest Science*, 26(4):532–542.

Ewing J (25 May 2017) 'Gmelina: tree mining, cardboard boxes and sawdust', *Quepolandia*, Quepos, Costa Rica, accessed 15 September 2023.

Gonzalez JE and Fisher RF (1994) 'Growth of native forest species planted on abandoned pasture land in Costa Rica', *Forest Ecology and Management*, 70:159–167.

Harwood CE and Nambiar EKS (2014) *Sustainable plantation forestry in South-East Asia*, ACIAR Technical Reports No. 84, Australian Centre for International Agricultural Research, Canberra.

Hoa NT and Catacutan D (2012) *History of agroforestry research and development in Viet Nam: analysis of research opportunities and gaps*, World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Hanoi, Vietnam.

Kien ND and Harwood C (2016) 'Timber demand and supply in northwest Vietnam: the roles of natural forests and planted trees', *Small-scale Forestry*, 16(1), doi:10.1007/s11842-016-9343-0.

Lamb D (2010) *Regreening the bare hills: tropical forest restoration in the Asia-Pacific Region*, Springer, Dordrecht.

Le DK and Ha HT (2017) 'Research and development of acacia hybrids for commercial planting in Vietnam', *Vietnam Journal of Science, Technology and Engineering*, 60(1).

Luong TH (2014) 'Forest resources and forestry in Vietnam', *Journal of Vietnamese Environment*, 6(2):171–177, doi:10.13141/jve.vol6.no2.pp171-177.

McElwee PD (2016) *Forests are gold: trees, people, and environmental rule in Vietnam*, University of Washington Press, Seattle.

McElwee P and Nghi TH (2021) 'Assessing the social benefits of tree planting by smallholders in Vietnam: lessons for large-scale reforestation programs, *Ecological Restoration*, 39(1–2):52–63.

Midgley SJ, Stevens PR and Arnold RJ (2017) 'Hidden assets: Asia's smallholder wood resources and their contribution to supply chains of commercial wood', *Australian Forestry*, 80(1):10–25.

Minh T, Neef A and Hoffmann V (2011) 'Agricultural knowledge transfer and innovation processes in Vietnam's northwestern uplands: state-governed or demand-driven?', *Southeast Asian Studies*, 48(4).

Nguyen L, Zimmer HC, Hung DV, Phuong NM and Tan NQ (2022) *Developing and promoting market-based agroforestry and forest rehabilitation options for northwest Vietnam*, final report for ACIAR project FST/2016/152, Australian Centre for International Agricultural Research, Canberra, Australia.

Nguyen TT, Koellner T, Le QB, Lambini CK, Choi I, Shin H, Van Dien P (2014) 'An economic analysis of reforestation with a native tree species: the case of Vietnamese farmers', *Biodiversity and Conservation*, 23(4):811–830.

Nguyen VQ, To XP, Basik Treanor N, Nguyen TQ, Cao TC (2018) *Linking smallholder plantations to global markets: lessons from the IKEA model in Vietnam*, Forest Trends Report Series – Forest Policy, Trade, and Finance, June 2018, Forest Trends, Washington, DC.

Nichols JD and Gonzalez JE (1992) *Especies nativas para la reforestacion en la zona sur de Costa Rica*, Organizacion para Estudios Tropicales and Universidad Estatal a Distancia, San Jose, Costa Rica.

Nichols JD (1994) '*Terminalia amazonia* (Gmel.) Exell: development of a native species for reforestation and agroforestry', *Commonwealth Forestry Review*, 73(1):9–13.

Perez-Ortega R (7 December 2018) 'Secondary forest in Costa Rica are re-cleared within decades', *Mongabay*, accessed 15 September 2023.

Powlen KA and Jones KW (2019) 'Identifying the determinants of and barriers to landowner participation in reforestation in Costa Rica', *Land Use Policy*, 84:216–225.

Rodriguez S (7 January 2022) 'How Costa Rica reversed deforestation and raised millions for conservation', *Dialogo Chino*, accessed 15 September 2023.

Roque RM (2004) 'Wood of *Gmelina arborea* in Costa Rica', *New Forests*, 28(2–3):299–307.

Sinacore K, Garcia EH, Howard T, van Breugel M, Lopez OR, Finkral AJ and Hall JS (2022) 'Towards effective reforestation: growth and commercial value of four commonly planted tropical timber species on infertile soils in Panama', *New Forests*, 54:125–142, doi: 10.1007/s11056-022-09906-0.

Solis CM and Moya RR (2004) *Terminalia amazonia* en Costa Rica [report], Instituto Tecnologico de Costa Rica, Cartago, Costa Rica.

Tatarski M (20 May 2021) 'Drastic forest development: Vietnam to plant one billion trees – but how?', *Mongabay*, accessed 15 September 2023.

Thacher T, Lee DR and Schelhas JW (1997) 'Farmer participation in reforestation incentive programs in Costa Rica', *Agroforestry Systems*, 35(3):269–289.

Tham LT, Darr D and Pretzsch J (2021) 'Analysis of Acacia hybrid value chains: a case study of woodchip and furniture production in central Vietnam', *Forest Policy and Economic*, 125:102401.

Truong DM, Yanagisawa M, Kono Y (2017) 'Forest transition in Vietnam: a case study of Northern mountain region', *Forest Policy and Economics*, 76: 72–80.

Zimmer HC, Thi HL, Lo D, Baynes J, Nichols JD (2018) 'Why do farmers still grow corn on steep slopes in northwest Vietnam?', *Agroforestry Systems*, 92(6):1721–1735.

Chapter 6

Developing appropriate teak-based agroforestry for smallholders in northern Laos

Mark J Dieters and A Nahuel A Pachas

Abstract

In this chapter, we present lessons from over a decade of agroforestry research in the northern uplands of Laos. As part of 2 projects funded by ACIAR, and in collaboration with Lao researchers, a network of agroforestry trials was established with the National Agriculture and Forestry Research Institute and many smallholder farmers. Here, we synthesise learning from this research, demonstrate where alley cropping systems with teak might be most appropriate, and attempt to optimise the design of these systems to minimise or eliminate waste, and so make them more efficient.

Teak-based agroforestry systems that incorporate alley cropping of perennial crops – such as banana (*Musa paradisiaca* L), broom grass (*Thysanolaena maxima*) and paper mulberry (*Roussonetia papyrifera*) – have in some instances been highly successful. Our analyses reveal that these systems could substantially increase the net present value of teak production in northern Laos for smallholder farmers. When compared to the traditional method (*taungya* system), alley cropping of annual crops (up to 2 years) and perennial crops (up to 7 years) with teak, can double the returns to the smallholder. Nevertheless, these returns require significantly more labour inputs and are not suitable in all circumstances for all smallholders. Careful consideration needs to be given to understanding the household's land requirements for production of both staple crops (upland rice) and cash crops (such as Job's tears and maize), and whether the additional labour requirements will adversely impact the household's other activities. Furthermore, households need to understand the income implications of converting some of their land to teak cultivation, until such time as the teak can be sold for production of sawn timber or squared logs.

For households where land is limited and household labour is primarily used for agricultural activities, alley farming can be a way for the household to invest in tree planting. Establishing a teak agroforestry plot with alley widths of 10 to 12 metres, combined with either 2 or 3 rows of teak, achieves initial stocking rates of at least 800 teak trees per hectare. Perennial crops are established in the first year, to assist with weed control, and to provide income from the third growing season. Intensive pre-commercial thinning should be practiced from the end of the fourth season. Using a lean farming approach, opportunities are identified to reduce waste and maximise values. With weeding found to be a major labour constraint to alley cropping in northern Laos, we discuss opportunities to reduce the labour required for weeding.

Acknowledgements

This research was funded by ACIAR in collaboration with The University of Queensland and the Lao National Agriculture and Forestry Research Institute, under ACIAR project FST/2004/057 'Enhancing on-farm incomes through improved silviculture management of teak in Luang Prabang Province of Lao PDR' and ACIAR project FST/2012/041 'Teak-based agroforestry systems to enhance and diversify smallholder livelihoods in Luang Prabang Province of Lao PDR'. We would like to thank and gratefully acknowledge the contributions to this research of the many smallholder households and our many Lao collaborators, especially Lao project leader Mr Somphanh Sakanphet who was instrumental in the establishment, management and coordination of the network of agroforestry trials reported here.

Introduction

Smallholder farmers in northern Laos have grown teak (*Tectona grandis* L. f.) for some 50 years in an agroforestry system known as *taungya,* which involves clearing and burning the site after a fallow period, then planting teak along with companion crops such as rice or maize for the first two years (Pachas et al. 2019a). Burning provides a short-term nutrient input to the companion crop and assists with the control of weeds. Following this initial 2-year window, manual weed control proves ineffective, and the continued cultivation of annual crops is not possible. This time-limited agroforestry system has led to a patchwork landscape where teak woodlots are intermixed in a complex (spatial agroforestry) system with annual and/or perennial crops, blocks left fallow for varying periods, and scattered remnant patches of native forests (Hansen et al. 1997). The conversion of catchments from shifting cultivation to teak woodlots has also been associated with increased soil erosion (Ribolzi et al. 2017).

Alley-cropping agroforestry systems are rare in Laos. In alley cropping, trees and companion crops are grown continuously on the same plot. Complex reasons can limit smallholders' uptake of alley cropping systems:

- Smallholders may have little exposure to this form of agriculture at the local or district level.
- Informal land ownership tends to encourage smallholders to expand upland farming activities through the clearing of degraded forests or previously cropped fallow land.
- Government policies promoting the planting of teak as a means of land ownership or usage may have resulted in increased land allocations to households who have previously grown teak woodlots.

Once demarcated as a teak woodlot, land is more easily identified and sold, thereby facilitating its sale to people who are not resident within the village boundaries. The valuation of teak woodlots in Laos has typically been determined by the total number of trees present, rather than productive capacity, mean annual increments, or any inventory to determine the value of the woodlot's standing timber. This has encouraged high initial stocking rates and discouraged pre-commercial thinning.

Within this context, teak agroforestry systems have been seen as a long-term investment, rather than as a tree crop that is actively managed for wood production. Teak, once planted, has typically not been managed in any systematic manner, with little understanding of the silvicultural practices that might improve productivity (Pachas et al. 2019a). Furthermore, markets for teak logs do not differentiate between pruned and unpruned trees, providing no incentive for teak growers to prune.

A typical management regime might involve planting teak in association with upland rice cultivation at a spacing of 3 x 3 m (measured on the slope, resulting in initial stocking rates of at least 1,100 trees/ha). Weed control is only practised in association with establishment of the companion crop. No active management of the tree crop occurs after the first 2 years. Thinning commences once the trees reach around 12 years of age, with the grower progressively removing the largest trees as they attain a marketable size, usually in response to their financial needs. While this low-input management scheme can return significant benefits to those smallholder farmers who retain their teak woodlot to maturity, it results in trees with reduced productive capacity (Pachas et al. 2019a). After 2 or 3 thinning operations (progressively removing the best trees), the farmer is often left with a residual stand dominated by poorly formed, suppressed trees of limited value.

Traditionally, agriculture in Lao upland areas has been based on a shifting model with long fallows of up to 10 years (Roder et al. 1995) between successive cropping cycles, without the use of fertilisers or other chemical inputs. As part of the formal land allocation process, the Lao PDR government has typically restricted each household to 4 parcels of upland cropping land within the geographical boundaries of their village, resulting in fallow periods of as little as 2 years, particularly where the household has no access to paddy land for rice cultivation. This leads to depletion of soil nutrients and an increased potential for soil erosion as each land parcel is cropped for 2 out of every 4 years. Households without access to off-farm income or to paddy land for the cultivation of rice are highly dependent on the allocated land area for food production and to underpin their livelihoods.

Agroforestry trial network

Prior experience has shown that agroforestry systems with contour planting of teak with wide inter-row spacing to provide alleys for the cultivation of companion crops can extend the period for effective cultivation of companion crops to as much as 10 years, which is half of a typical teak rotation in northern Laos. ACIAR funded the establishment of a network of 93 teak-based agroforestry trials across 5 districts of Luang Prabang Province in northern Laos between 2009 and 2015 (Figure 6-1). These trials involved the direct participation of 78 smallholders from 29 villages, across 6 districts of the province: Ngoi, Pakxieng, Pak-Ou, Phonxay, Xieng-ngeun and Viengkham. In this region, most households are engaged in upland agriculture. The climate is tropical monsoon, with a rainy period from April/May to mid-October/November followed by an extended dry period from December to April.

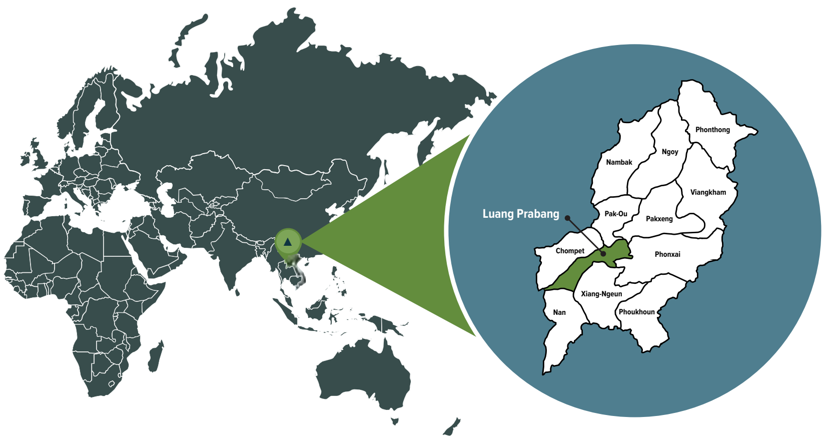

Figure 6-1: Collaborative trials were established in Luang Prabang Province, Laos. (▲)

In 2009 and 2010, the Upland Agriculture Research Center (UARC – a research centre within the National Agriculture and Forestry Research Institute) identified farmers interested in participating in the trials. These trials were all located within the catchment of a single village (Ban Phonsavang, Xieng-ngeun district). Subsequently, in 2014 and 2015 the staff of the local District Agriculture and Forestry Office (DAFO) provided the link between the project and smallholders in each district. Prospective participating smallholders (male and female) were interviewed to ensure that they understood the aims of the project, their commitments to the project and potential consequences of tree planting on the rotational management of their remaining upland fields.

The first 10 trials were established using either a single row (1.8 × 8 m; 650 trees/ha) or a paired-row configuration. Under the paired-row configuration, trees were spaced 1.8 m along the rows, and 2.1 m between paired rows, and trees in adjacent rows were offset by 0.9 m to maximise inter-tree spacing within paired rows (Figure 6-2). Each pair of rows were planted 8 m apart giving a spacing of (1.8 × 2.1 × 8 m; 1,100 trees/ha). Based on the promising early results of the first trials, an additional 83 trials were established using this paired-row configuration. The spacing between adjacent paired rows was set at 8, 10, 12 or 15 m, giving initial planting densities of 1,100, 918, 788 or 650 trees/ha, respectively. In each trial site, 2 alley widths were tested, and the trials were set up as a balanced set of paired-comparisons to test all possible combinations, with paired-comparisons replicated across trial sites within a district (Table 6-1). That is, trial sites were established using all 6 possible paired combinations of the initial spacing between paired rows: 8–10 m (1), 8–12 m (2), 8–15 m (3), 10–12 m (4), 10–15 m (5) and 12–15 m (6). Trial sites ranged from 0.4 to 2 ha. Teak planting rows were aligned along the contour.

The project provided teak stumps sourced by the National Agriculture and Forestry Research Institute at no cost to the collaborating farmers. The farmers (both male and female smallholders) were responsible for planting the teak in the planting positions marked. They were also responsible for the maintenance and weeding of each trial, which they largely conducted incidentally as part of their management of the annual crops. Each household decided on the companion crop(s) that best suited their needs, and sourced all seeds (or vegetative material) at their own expense. Recommended management practices for the teak trees were discussed with the farmers during the initial project meetings and during regular visits to each trial. However, the decision whether or not to undertake any additional work was entirely the decision of each household. As such, some households decided to plant a companion crop in the second year, while others did not.

Permanent measure plots were established for monitoring the growth in height and in diameter at breast height. All surviving trees in these plots were measured annually during the dry season. Each year, some sites were discarded due to lack of maintenance by the farmer which had resulted in poor survival and/or growth rates of the trees. In January 2018, all sites were reviewed and classified based on the growth and survival of the teak trees – good, average, poor and unsuccessful.

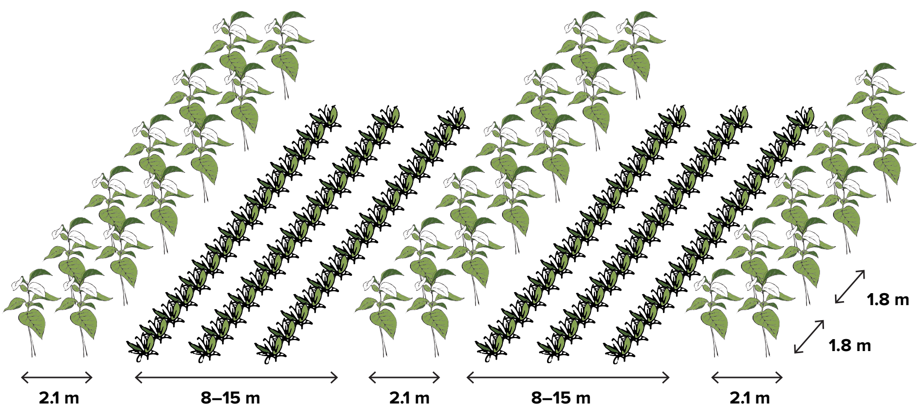

Figure 6-2: Design of the alley cropping system used to establish the network of agroforestry trials. Teak was planted in paired rows, with alley widths of 8, 10, 12 or 15 m.

Table 6-1: The number of agroforestry trials established in 2014 and 2015 with each combination of initial spacing between paired teak rows (8–10 m, 8–12 m, 8–15 m, 10–12 m, 10–15 m and 12–15 m) or single rows (8 m and 15 m)

Year	District	8–10 m	8–12 m	8–15 m	10–12 m	10–15 m	12–15 m	8 m	15 m	No. of sites
2014	Phonxay	2	2	2	2	2	3			**13**
	Pakxieng	2	2	1	2	2	2	1	1	**13**
	Pak-Ou		1	1	2		2			**6**
2015	Phonxay	2	2	1	3	1	3	2		**14**
	Pakxieng		1		1					**2**
	Ngoi	3	6	4	4	3	3			**23**
	Viengkham	2	2	2	2	2	2			**12**

Economic analyses

The costs and prospective returns were analysed, using detailed actual costs and revenues through to 2018 and the estimated revenue from the sale of the timber at 15 years of age. The cost of planting material to establish the teak trees and the companion crops was compiled using market prices as of 2018, and an exchange rate of US$1 = 8,500 Lao kip (LAK). Information on the labour inputs and the yield of companion crops was compiled from a subset of the 30 smallholder participants in Phonxay district (trials established in 2014–2015), on the assumption that these costs and returns were representative of all participants. Labour is usually unpaid, provided by family members of the household or under community work at the village level, but was valued at US$4.7/person-day (LAK40,000).

To estimate the volume of teak logs, growth data from the 6 oldest agroforestry trials were used to estimate the growth to 15 years of age. Using observed annual increments, estimated site index (Dieters et al. 2014), an assumed stocking of 514 trees/ha at 15 years, stump height of 0.15 m, log length of 2.1 m, and the taper equation of Warner et al. (2016), we estimated the merchantable volume (m^3/ha) for each 5-cm girth class by multiplying the estimated number of trees per girth class by predicted merchantable values.

Yield of the companion crops was obtained for the first 10 sites via interviews conducted in 2009, 2010, 2011 and 2012. Prices obtained from the sale of Job's tears (*Coix lacryma-jobi*), bananas (*Musa* sp.) and broom grass (*Thysanolaena maxima)* were taken as the average local prices in 2018: US$0.29 (LAK2,500) per fresh kg of Job's tears; US$0.17 (LAK1,500) per hand of banana; and US$0.29 (LAK2,500) per fresh kg of broom grass.

Expected returns from the sale of teak logs were based on the average price in this region for standing trees. These values were obtained using roundwood prices for sawlogs according to the small-end diameter of the log. The prices per cubic metre for each log category were: US$29.4, US$47.1, US$100, US$117.6 and US$176.5 for log class 1 (12–15 cm), class 2 (15–18 cm), class 3 (18–20 cm), class 4 (20–30 cm) and class 5 (more than 30 cm), respectively. These prices were about 60% lower than for logs delivered to the mill gate and allow for the additional costs of harvesting, extraction and transportation.

The financial and economic analyses were carried out using the indicators: net present value (NPV), equivalent annual annuity (EAA), benefit:cost ratio (BCR) and internal rate of return (IRR), which are recommended for evaluating forestry and agroforestry projects (Cubbage et al. 2015). We used a 10% discount rate (that is, the average borrowing bank rate in Luang Prabang province at that time) and a 4% inflation rate. A sensitivity analysis was used to evaluate the effects of changing the discount rate (to 12% and 14%), increasing the daily labour rate (by 10% or 20%), varying the log price (±20%), and compared the results to a *taungya* agroforestry system with a 2-year period of companion cropping.

Results of trials

Of the 93 agroforestry trials, 60% (6/10) of the trials established in 2009–2010 were judged as successful via survival and tree growth rate, compared with only 49% (40/83) of those established in 2014–2015. Unsuccessful trials were primarily related to a lack of weed control, which adversely affected survival and growth of the teak, with the poorest growth and survival associated with farmers who did not grow companion crops after the first year and/or where the trials had been burned. Trials located in Viengkham were also at comparatively higher altitudes, which proved unsuitable for the cultivation of teak in many cases.

Other factors identified that may have affected the success rate were:

- the age of the participant – older farmers demonstrated less labour capacity and were less motivated to grow companion crops with the teak
- the proximity of the agroforestry plot to the village or other upland fields – closer plots were visited more regularly
- the prevalence of grazing animals (goats, cattle and buffalo) – this was linked to increased levels of damage from uncontrolled grazing.

Teak growth rates

Growth rates of the teak varied by location and year of planting. The mean diameter and height of the teak trees in the remaining 6 trials established in 2009 or 2010 (Figure 6-3) indicate slightly better growth in 2009 trials, reflecting inherent differences in the sites and intensity of management applied by individual farmers. Overall, the trials achieved a site index (SI15) of 13, which puts these trial sites at the lower productivity range of teak woodlots in Luang Prabang (Dieters et al. 2014). The mean height and diameters recorded in the remaining 40 trials established in 2014 or 2015 (Table 6-2) show similar growth rates to those observed in the earlier trials in Phonsavang village (compare Table 6-2 to Figure 6-3), with teak trees generally achieving mean heights of 5–6 m (or better) by 4–5 years of age across all spacing treatments.

There was also a trend of decreasing height associated with increasing alley width, but greater diameter at the widest alley width (15 m), which is broadly consistent with results from a Nelder wheel experiment of teak grown on a much more productive site near the Mekong River (Pachas et al. 2019b). This supports the use of data from the oldest trials to predict merchantable volumes at 15 years of age from these agroforestry systems.

Table 6-2: Mean height and diameter at breast height of the teak trees by year after planting, and width of the alleys between paired rows of teak, for agroforestry plots planted in 2014 and 2015

	Alley width between paired teak rows							
	8 m	10 m	12 m	15 m	8 m	10 m	12 m	15 m
	Total height (m)				Diameter (cm)			
Age (years)	**Planted in 2014**							
1	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.1	-----	-----	-----	-----
2	1.1±0.1	1.4±0.1	1.0±0.1	1.3±0.1	0.7±0.1	1.2±0.1	0.6±0.1	1.0±0.1
3	2.5±0.1	3.2±0.5	2.1±0.2	3.6±0.4	2.4±0.1	3.4±0.2	2.1±0.4	3.9±0.5
4	4.8±0.3	5.6±0.4	5.4±0.8	6.7±0.6	5.3±0.3	5.9±0.5	5.8±1	6.9±0.6
5	7.3±0.3	7.8±0.5	6.6±0.8	8.3±0.8	7.0±0.4	7.3±0.6	6.8±1.2	8.5±0.6
Age (years)	**Planted in 2015**							
1	0.3±0.1	0.3±0.1	0.3±0.1	0.2±0.1	-----	-----	-----	-----
2	1.8±0.1	1.8±0.1	1.6±0.1	1.5±0.1	1.9±0.2	2.1±0.2	1.7±0.2	1.7±0.2
3	3.8±0.1	4.1±0.2	3.9±0.3	3.5±0.3	4.2±0.1	4.4±0.2	4.0±0.2	3.8±0.4
4	5.5±0.4	6.5±0.3	5.0±0.2	5.5±0.4	5.3±0.4	6.4±0.3	5.1±0.3	5.4±0.4

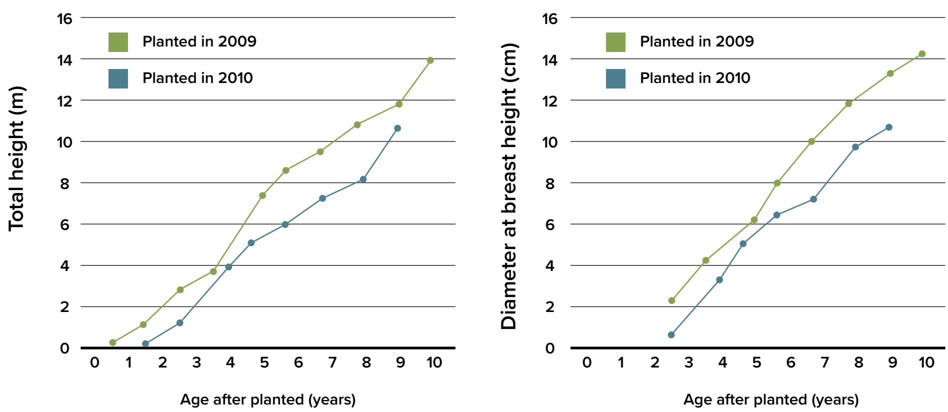

Figure 6-3: Mean total height (left) and diameter at breast height (right) of teak in agroforestry trials established in Phonsavang village in 2009 and 2010

Companion cropping

The yield of companion crops across the first 4 growing seasons was collated for the 10 agroforestry sites planted in 2009 and 2010 in Phonsavang village (Table 6-3). The farmers intercropped their plots with several combinations of annual and perennial species – commonly, Job's tears (*Coix lacryma-jobi*) with banana (*Musa paradisiaca*) and broom grass (*Thysanolaena maxima*). All farmers grew Job's tears during the first season, with only 50% cultivating it in the second season and none in the subsequent years. Additionally, the Job's tears yield in the second season was 17% lower than in the first season.

The banana yield increased in the second and third years, while the broom grass yield decreased with the increasing age of the teak. Only 3 farmers who grew annual crops in the first 2 years grew no companion (perennial) crops in the subsequent years, while the remaining farmers were able to harvest bananas, broom grass or paper mulberry (*Roussonetia papyrifera*) for at least 4 years after planting teak. Some farmers continued to harvest bananas for up to 7 years.

Table 6-3: Average yield (kg/ha) of companion crops cultivated in trials established in 2009 and 2010 (standard error is included in parentheses)

Crop	Average yield (kg/ha) per growing season (1st–4th)			
	1st	2nd	3rd	4th
Job's tears	1,911 (848)	1,578 (458)	------	------
Banana	1,118 (681)	1,468 (531)	1,250 (213)	866 (173)
Broom grass	362 (148)	335 (134)	108 (24)	106 (37)
Paper mulberry	127 (37)	106 (36)	123 (68)	71 (53)

Inputs, costs and returns

The labour required was high, with labour required for clearing and site preparation before planting (~42 days/ha) (Table 6-4). Between 185 and 131 days/ha were required for growing annual crops during the first and second year, respectively, after planting teak.

All costs and returns for all activities were taken into consideration as part of the economic analyses (Table 6-5). The total cost for establishing teak, annual and perennial crops without consideration of the labour costs was US$282/ha. However, when labour was included, the total investment necessary reached US$1,158/ha. Labour comprised approximately two-thirds of the overall cost. These labour costs are associated primarily with the cultivation of the annual crop (Job's tears in this case) and teak planting was largely incidental to the cropping activities. To simplify the comparisons, we considered only the companion cropping involving the cultivation of Job's tears as the annual crop in the first 2 years, along with banana planted at the same time as the teak, combined with the harvesting of broom grass from the plot.

Table 6-4: The average labour used for alley cropping teak with companion crops in Phonxay district (standard error is included in parentheses)

	Intercropping season 1	Intercropping season 2
Villages	Thapho, Pounpao, Thakham, Donexay, Sopchiar	Nambor, Houmyha, Thakham
Crops	upland rice, Job's tears, sorghum	upland rice, Job's tears, maize
No. of farmers interviewed	12	6
	Labour days/ha	
Site preparation	42 (13)	32 (8)
Planting	30 (13)	24 (8)
Weeding	50 (14)	33 (16)
Harvesting	35 (14)	28 (4)
Transport	28 (12)	14 (3)
Total labour	**185 (51)**	**131 (23)**

In determining the average yields and returns from the annual (Job's tears) and perennial (banana and/or broom grass) companion crops in trials, the economic analyses undertaken with farmers from Phonsavang village were used (Table 6-6). The total gross income from cash crops were:

- Job's tears: US$1,018/ha
- Banana (from years 1 to 7): US$1,394/ha
- Broom grass (from years 1 to 6): US$415/ha.

The major source of income arose from the predicted sale of timber at year 15, estimated as US$6,810/ha (Table 6-6). Total merchantable volume estimated at 15 years of age was 76.5 m^3/ha with 70% of the volume comprised of log class 1 (12–15 cm) and log class 2 (15–18 cm). Due to the low productivity of the site (5.1 merchantable m^3/ha/year), the simulations did not indicate any logs with a small-end diameter of more than 30 cm. This simulation reflects a short-rotation strategy for teak – plant at 1,100 trees/ha, pre-commercial thin to around 600 trees/ha between 4–6 years of age, then harvest all remaining trees (500–550 trees/ha) at 15 years of age.

Table 6-5: **Inputs, costs, labour requirements by year and by activity for teak agroforestry systems in Luang Prabang, Laos**

Activity	Year	Labour (days/ha)	Cost LAK/ha	Cost US$/ha
Slashing and burning	0	60	2,400,000	282.30
Planting teak	0	10	400,000	47.00
Sowing annual crops (e.g., upland rice in year 0 and Job's tears in year 1)	0	35	1,400,000	164.70
	1	20	800,000	94.10
Planting perennial crops (e.g., banana)	0	10	400,000	47.00
Weeding	0	40	1,600,000	188.20
	1	30	1,200,000	141.10
	2	10	400,000	47.00
	3	10	400,000	47.00
	4	5	200,000	23.50
	5	5	200,000	23.50
Harvesting annual and perennial crops	1	35	1,400,000	164.70
	2	49	1,960,000	230.60
	3	24	960,000	113.00
	4	15	600,000	70.50
	5	10	400,000	47.00
	6	5	200,000	23.50
	7	3	120,000	14.10
Singling and form pruning	2	3	120,000	14.10
	3	3	120,000	14.10
Pruning	5	10	400,000	47.00
	6	10	400,000	47.00
	7	10	400,000	47.00
Thinning	5	5	200,000	23.50
Transporting product to roadside	1	15	600,000	70.50
	2	39	1,560,000	183.50
	3	24	960,000	113.00
	4	15	600,000	70.50
	5	10	400,000	47.00
	6	5	200,000	23.50
	7	3	120,000	14.10
Other variable costs				
Job's tear seeds (37kg/ha @ LAK3,000/kg)	0		111,000	13.00
	1		111,000	135.00
Teak seedlings (833 seedlings/ha @ LAK1,500/seedling)	0		1,249,500	147.00
Banana suckers (300 suckers/ha @ LAK3,000/sucker)	0		900,000	105.80

Table 6-6: Yield, price and revenue for annual and perennial crops. Merchantable teak volume was estimated by simulating teak growth at site index at base age of 15 years = 13. Yields and teak growth data are from the trials established in 2009 and 2010 at Phonsavang village.

Crop	Price	Year	Yield†	Income	
				LAK/ha	US$/ha
Job's tears	US$0.29/kg (LAK2,500)	1	1,900	4,750,000	558.80
		2	1,560	3,900,000	458.80
Banana	US$0.12/hand (LAK1,000)	2	1,500	2,250,000	264.70
		3	2,000	3,000,000	352.90
		4	2,000	3,000,000	352.90
		5	1,500	2,250,000	264.70
		6	600	900,000	105.80
		7	300	450,000	52.90
Broom grass	US$0.29/kg (LAK2,500)	1	360	900,000	105.80
		2	350	875,000	102.90
		3	350	875,000	102.90
		4	200	500,000	58.80
		5	100	250,000	29.40
		6	50	125,000	14.70
Teak by log class		15	29.8	20,570,000	3,504.50
12–15 cm		15	24.2	6,645,810	2,420.00
15–18 cm		15	16.6	1,674,330	781.00
18–20 cm		15	6.7	0	197.00
20–30 cm		15	0	0	0
>30 cm		15	0	0	0

† Yields are presented in kg/ha for Job's tears and broom grass, hands/ha for banana, and m^3/ha for teak.

In the baseline scenario used (Table 6-7), the simulated short-rotation teak agroforestry system yielded an NPV of US$1,519/ha (at a 10% discount rate), equivalent to a net income per year of about US$200/ha, and an IRR of 22%. Realistically, it might be assumed that prices will increase in real terms due to the increasing scarcity and higher future demand for teak timber and/or due to better pruning and silvicultural practices. Under this scenario, with the same labour rates and discount rate, a 20% increase in timber value delivers an NPV of US$1,845/ha, an EAA of US$243/ha, and an IRR of 23.5%. While it is reasonable to assume that labour costs will increase in real terms, when we considered a 10% increment of the labour cost and a 20% increase in the timber price, we still achieve a better outcome than the baseline scenario (NPV of US$1,621/ha, EAA of US$213/ha) with an IRR of 20.6% (Table 6-7). Nevertheless, increasing rotation length will increase the proportion of logs in the higher-value, large-diameter classes and increase the merchantable volume. By comparison, simulations for teak agroforestry systems in Indonesia (Khasanah et al. 2015) to 30 years of age, based on similar early-age increments, suggest much higher merchantable volumes at the end of the rotation.

Agroforestry alley-cropping scenarios that combined annual and perennial crops during longer periods (for example, up to 7 years) registered better financial outcomes than the traditional 2-year intercropping system (*taungya*) that has been practised in Laos which delivered an NPV of US$831/ha, EAA of US$109/ha and IRR of 15.5% (Table 6-7) – just over half that achieved from alley cropping with teak over 15 years. Compared to the traditional *taungya* system with companion crops in only the first 2 years of the life cycle of the teak woodlot, alley cropping could double the NPV and EAA, with a cost–benefit ratio of 2.5 compared to 1.9 under the base scenario (Table 6-7).

Table 6-7: Sensitivity analysis of the effect of increases to the discount rate (10%, 12%, 14%), labour cost (2018 cost, 10% and 20% increment respectively) and wood price (2018 price, 20% decreased and 20% increased) on NPV, EAA, BCR and IRR of teak-based agroforestry systems (up to 7 years of companion cropping) and for a *taungya* system (2-year companion cropping). Negative values are shown in brackets.

	Teak-based agroforestry systems (7 years of companion crops)								
Discount rate	**10%**	**12%**	**14%**	**10%**	**12%**	**14%**	**10%**	**12%**	**14%**
Labour cost	2018 cost			2018 cost			2018 cost		
Wood price	2018 price			20% lower			20% higher		
NPV ($)	1,519	1,090	761	1,193	842	570	1,845	1,339	952
EAA ($)	200	160	124	157	124	93	243	197	155
BCR	2.5	2.1	1.7	2.2	1.8	1.6	2.8	2.3	1.9
IRR (%)			22.0			21.1			23.5
Labour cost	10% higher			10% higher			10% higher		
Wood price	2018 price			20% lower			20% higher		
NPV ($)	1,295	874	551	969	625	361	1,621	1,123	742
EAA ($)	170	128	90	127	92	59	213	165	121
BCR	2.2	1.8	1.5	1.9	1.6	1.3	2.5	2.0	1.7
IRR (%)			19.4			17.9			20.6
Labour cost	20% higher			20% higher			20% higher		
Wood price	2018 price			20% lower			20% higher		
NPV ($)	1,072	658	342	746	409	151	1,398	907	533
EAA ($)	141	97	56	98	60	25	184	133	87
BCR	1.9	1.6	1.3	1.6	1.3	1.1	2.2	1.8	1.5
IRR (%)			17.0			15.5			18.2
	Taungya systems (intercropping only 1–2 years)								
Discount rate	**10%**	**12%**	**14%**	**10%**	**12%**	**14%**	**10%**	**12%**	**14%**
Labour cost	2018 cost			2018 cost			2018 cost		
Wood price	2018 price			20% lower			20% higher		
NPV ($)	831	452	168	505	203	(23)	1,157	701	359
EAA ($)	109	66	27	66	30	(4)	152	103	58
BCR	1.9	1.5	1.2	1.6	1.2	0.9	2.3	1.8	1.4
IRR (%)			15.5			13.8			17.0

NPV = net present value; EAA = equivalent annual annuity; BCR = benefit:cost ratio; IRR = internal rate of return

Diverse smallholders and forest transition pathways

Should all smallholder famers in northern Laos adopt the alley-cropping agroforestry system? Given the high failure rate of trials in the agroforestry network reported above, the answer is unequivocally 'no'. Agroforestry systems involving alley cropping are not appropriate for all smallholder farmers.

Foremost, a 'one size fits all' model will not meet the diverse requirements of smallholders. Newby et al. (2012 and 2014) provide a context for agroforestry activities in northern Laos. According to Newby et al. (2012), households with a greater ability to invest in teak cultivation and to retain these woodlots until maturity had:

- a longer history of settlement in the village
- an older and better educated household head
- access to paddy land for rice cultivation
- family members who had access to off-farm income.

By contrast, households that were purely dependent on the cultivation of upland fields (either allocated land or rented land) to produce rice, and as their primary livelihood strategy, had difficulty planting teak and then retaining any teak planted until maturity.

Building on this work, Newby et al. (2014) identified 3 forest transition pathways:

- economic development pathway
- smallholder intensification pathway
- state policy pathway.

The farmers identified by Newby et al. (2012) who had successfully invested in teak growing in the past were primarily on the economic development pathway. For these households, labour scarcity rather than forest scarcity is the major driver (Newby et al. 2014). Labour scarcity primarily arose due to the household head being older and the younger members of the household working off farm. In such a scenario, the most appropriate approach for the household is to develop teak woodlots with the traditional *taungya* system. Many of these households choose to rent upland plots to households on the other pathways, to grow annual crops for up 2 years, in exchange for planting teak and a share of the crop harvested.

By contrast, households on the intensification pathway typically have limited or no access to paddy land for cultivation of rice, limited access to off-farm income, and their household labour is concentrated on agricultural activities (Newby et al. 2014). Households without access to paddy land risk underestimating the amount of land required to meet their household needs after some of their allocated upland fields have been converted to a teak woodlot, resulting in reduced fallow periods and declining yields of annual crops. This may result in them selling the teak woodlot, renting land for cropping activities, or allocating more labour to off-farm activities (Newby et al. 2014). For these households, an alley-cropping agroforestry system is seen as the most appropriate way to cultivate teak (Newby et al. 2014). It allows the household to keep generating income from perennial crops (such as banana, pineapple, paper mulberry, broom grass) alongside the teak for 4–7 years, which will mitigate land constraints, allowing them to invest in teak production, while at the same time maintaining household income from agricultural activities.

Households on the state policy pathway must carefully consider any decision to devote resources to long-term production systems, such as growing teak. There is considerable risk that they will not be able to retain the teak until maturity and, if forced to sell, they will not realise the value of their investment in tree growing.

The categorisation of households on forest transition pathways aligns strongly with observed patterns of the success or failure of households involved in the network of agroforestry trials reported above. Many of the agroforestry plots that failed involved older (more than 50 years of age) participants, with limited household labour, who had been attracted to the project because teak planting material was provided at no cost to the household. These growers can be best considered as being on the economic development pathway. Despite a rigorous process of interviewing and informing them of the labour requirements of the alley-cropping systems proposed, it later became apparent that several of them believed that only a little more labour would be required than for traditional *taungya* systems. Many also thought that intercropping beyond the second year would not be possible.

The reasons for failure were more complex for participants from households on the other 2 pathways. But failure often resulted because perennial crops were not established with the teak and annual crops in the first year, despite this being recommended to all participants. Furthermore, some of these households had limited land for agriculture and, where a perennial companion crop was not established, some households needed to grow annual crops with the teak in the fourth year to meet household requirements. In the absence of chemical weed control, they used traditional methods of cutting and burning to clear the alleys and prepare for planting of annual crops, which, unfortunately, frequently led to significant mortality in the adjoining teak rows. The other indicator of failure for this group was the location of the agroforestry plot in terms of its proximity to the village or to other upland plots. If the participant needed to journey a significant distance to visit the agroforestry plot, then maintenance and weeding frequently dropped off after the first growing season.

Weeding represented over 60% of the labour requirement in the agroforestry system tested, with much of this occurring during the rainy season. However, the agroforestry plot is competing for household labour inputs with other agricultural activities, requiring the household to prioritise labour, limiting risk and maximising returns. Ducourtieux (2006) characterised how household labour is managed in the upland regions of Laos; annual crops are typically grown for 2 years on each plot following clearing and burning, meaning that household labour is allocated to a plot cleared and sown in the current year, and also to a plot being cultivated for a second year. As demonstrated in the agroforestry trials (Table 6-3), yields of annual crops are typically lower in the second growing season than the first. As such, when labour is limited, households will prioritise the crop that they consider will provide the highest return, which is the crop growing on the site that has been cleared, burned and sown in the current season.

An alley-cropping agroforestry system is therefore appropriate for households who have limited land but have sufficient labour to grow and harvest perennial crops from the alleys and to control weeds. Households with excess land but limited labour might consider establishing a teak woodlot using the *taungya* agroforestry system. Furthermore, to best ensure success of alley cropping in a teak agroforestry system, the location of the plot should be considered, both in terms of proximity to the village and the future ability to extract and transport perennial crops to market.

Designing an appropriate alley-cropping teak agroforestry system

Now we come to the question of what is the most appropriate design for a teak agroforestry system using alley cropping. What is the 'best' (most appropriate) width for the alleys, and how should the teak trees be arranged as to the spacing between trees/rows and the number of rows? The design used in the agroforestry network described above used paired rows of teak, planted along the contours, with 1.8 m between trees within a row and 2.1 m between rows. The alley widths were 8, 10, 12 or 15 m, resulting in initial stocking rates of 1,100, 918, 788 and 690 trees/ha, respectively. Experience from these trials suggests that alleys of 8 m are too narrow, not allowing sufficient space for the cultivation of perennial crops, restricting crop growth after 4–5 years. Pachas et al. (2019) also demonstrated a reduction in the yield of the companion crops (cassava, maize and pigeon peas) when the spacing between trees was reduced from 10 m to 8 m. However, alley widths of 15 m result in a low initial stocking rate of teak and an increased workload to control weeds, particularly in the early years while the perennial crops are becoming established. Alley widths of 10–12 m will therefore often be the most appropriate. Khasanah et al. (2015) also demonstrated the advantage of lower initial stocking rates (625 trees/ha compared to 1,111 or 1,600 trees/ha), and intensive early thinning (that is, precommercial thinning at 5 years of age, removing 50% or more of the trees), both on long-term productivity and the final value of the teak crop, and also on the productivity and value of the companion crop. Further, Winara et al. (2022) pointed out that while the productivity of companion crops under teak in an agroforestry system is lower than in a monoculture crop, the crops harvested are nevertheless important for food security and for maintaining household livelihoods. Also, intensification of companion cropping has the dual benefits of increasing yield of the companion crop (fertiliser increased maize yields from 4.3 to 6.5 tonne/ha in a young teak agroforestry plot; Karimuna et al. 2022) and increasing productivity of the teak crop (Khasanah et al. 2015).

Figure 6-4: (Left) A highly successful teak and banana agroforestry system was established by Mrs Bi and Mr Bat on their farm in Phonxay district. (Right) Aerial view of the young plot (third year after planting)

Credit: (Left) Jonathan Newby and (right) Nahuel Pachas

There have been some significant recent changes to the relevant legal framework in Lao PDR. Hilary Smith remarks:

> […] while the new Lao forestry law (No 64/NA) and the Decree on plantation promotion are silent on initial stocking levels for all species, the most relevant change is the Implementation Instruction No.2492/MAF, 2020 on the National Registry of the Plantation Forests and Certified Planted Trees, which has reduced the initial minimum stocking to 800 trees/ha (for species other than rubber) and allows for thinning […]
>
> — Hilary Smith, Latitude Forest Services, (personal communication 2023)

These changes now make it possible to recommend initial stocking rates of 800–850 trees/ha and the implementation of intensive pre-commercial thinning. Previously, such a regime would have prevented registration of the teak plantation in Lao PDR.

For a 10-m alley width, paired teak rows with spacing of 2 m between trees and 2 m between rows will achieve a stocking of 833 trees/ha (Pachas et al. 2019a). However, if the alley width is increased to 12 m, both inter-tree and inter-row spacing must be reduced to 1.8 m to achieve 805 tonne/ha. To achieve a target stocking rate of 800–850 trees/ha and increase the distance between trees, triple rows of teak can be used rather than paired rows. For triple rows, with a 10-m alley width, an initial stocking of 845 trees/ha can be achieved by setting inter-row/tree spacing at 2.4 m, while for a 12-m alley width, an initial stocking of 831 trees/ha is achieved with 2.2 m between rows/trees.

Use of more than triple teak rows is not recommended for the following reasons:

- Only paired rows have been evaluated.
- Additional rows are likely to increase variability in tree growth.
- Additional rows will be highly dependent on intensive management of inter-tree competition via regular thinning.
- As the number of teak rows increases, the relative allocation of land to teak compared to alley cropping also increases, thus reducing the capacity to produce companion crops per unit area.

Where the production of companion crops is of high importance to the household and sufficient labour is available to manage weed control and the companion crop, then 12-m alleys with 2 or 3 teak rows are likely to be the most appropriate. There are, however, other trade-offs in terms of weed control and tree growth that should be considered in developing the most appropriate agroforestry system.

Reducing waste using the 'lean farming' approach

Newby et al. (2014) noted during interviews with farmers when discussing pre-commercial thinning that, 'When discussing thinning practices with farmers and village heads, they often expressed a feeling of regret (*siadai*) about removing small trees without being able to obtain some income from them'**.** This means that it is very difficult to convince farmers to remove (that is, pre-commercially thin) suppressed trees that are close to a commercial size. Hence the importance of pre-commercial thinning at an earlier age (4–6 years), when the trees to be removed are small and the labour required is relatively low. Small trees can be felled quickly with a machete and used as fuelwood.

As such, there is less waste and little regret attached to pre-commercial thinning at 4–6 years of age compared to thinning at 8–10 years of age. Khasanah et al. (2015) also demonstrate significant increases in the NPV of teak agroforestry systems when intensive thinning is done at 5 years of age, removing 25% to 50% of the trees.

This concept of *siadai* is important to consider when attempting to design appropriate agroforestry practices for teak in Laos. It reflects an ingrained reluctance to waste anything. Such a feeling is also evident in many Western countries among older people who lived through the Depression and the Second World War. Waste is anathema to the typical Lao smallholder. One project participant was devastated when his paddy land was resumed for the construction of a road. The loss of productive paddy land was viewed as an extreme form of waste. Given this waste-avoidance perspective, the principles of 'lean farming' (Hartman 2015) are relevant. Under lean-farming principles, every activity is regarded as being either:

- an activity that adds value
- an activity that is necessary, but which does not add value (termed Type 1 *muda*)
- an activity that does not add value and which is unnecessary (Type 2 *muda*).

Muda is the Japanese word for wastefulness. According to Hartman, Type 1 *muda* should be minimised and Type 2 *muda* should be eliminated (Hartman 2015:55). This conceptual framework reflects the Lao concept of *siadai* and we have attempted to use this classification for all activities in a teak agroforestry system (Table 6-8) to see how wastefulness can be avoided or eliminated.

Table 6-8: Activities in the lifecycle of a teak agroforestry plot classified according to lean-farming principles

Activity	Adds value	Type 1 *muda*†	Type 2 *muda*‡	Explanation
Clearing and burning		✓		Clearing and burning are a necessary activity in the establishment of a teak agroforestry plot but do not add any value. Labour could be reduced by using a motorised brush cutter.
Planting	✓			Sowing and planting companion crops and teak trees adds value. Using the most appropriate planting arrangement, accurately measuring planting distances, and carefully orientating the crops along contours maximises the value obtained.
Planting a perennial crop	✓			Including a perennial crop in the agroforestry system adds value and also reduces waste. Competition from the developing perennial crop helps control weeds in the alleys in the third and following years. As such, the successful establishment of perennial crops in the first year is fundamental to the success of an agroforestry system, in the absence of efficient chemical (herbicide) or mechanical (ploughing) aids.
Travelling to and from the plot		✓		Travelling between the village and the agroforestry plot is to some extent necessary, as it is impossible for the plot to be located within the village. However, it needs to be minimised. This can be achieved by carefully selecting the site; eliminating unnecessary travel; bringing the correct tools when visiting the site (e.g., to allow some weeding, pruning, or thinning while at the site); incorporating travel with other activities (e.g., collecting non-timber forest products); and/or using motorised transport, such as a small tractor.

Activity	Adds value	Type 1 *muda*†	Type 2 *muda*‡	Explanation
Weeding		✓		To some extent weeding is necessary, but if the site is prepared so that it is free of any weed seed, then weeding is largely eliminated. Hence weeding might be considered Type 1 or Type 2 *muda*. The amount of weeding is highly dependent on the tree spacing, alley width and the establishment of a perennial crop. Strategies must be adopted to minimise weeding, as this is one of the single largest demands on labour inputs. Mechanical and chemical weed control methods also reduce wastefulness. Shared community labour is another way to minimise wastefulness of resources, as weeding can be accomplished more quickly, when required, but it requires collaboration and coordination of activities (Type 1 *muda*).
Harvesting companion crops	✓			Harvesting and selling companion crops increases value, improves cash flows, and delivers livelihood benefits to the household for 7 (or more) years after planting the teak.
Form pruning	✓	✓		Form pruning adds value, in that single straight trees have higher value than forked or bent trees. Ideally, form pruning could be eliminated by having better-quality planting stock and eliminating sources of damage (e.g., cattle browsing).
Pre-commercial thinning	✓	✓		In itself, pre-commercial thinning does not add value, but it is necessary for the overall health, quality and vigour of the stand. Waste associated with pre-commercial thinning can be minimised by thinning as early as possible (i.e., as inter-tree competition commences) and progressively removing the poorest trees at 4–6 years of age, so as not to affect the growth of the residual trees. Removing less productive smaller or poorly formed trees concentrates stand growth on fewer better-formed trees, thereby increasing value.
Pruning		✓	✓	Pruning is wasteful, as in itself it does not add value, but can be necessary to obtain teak logs of the highest value at final harvest. To minimise wastefulness associated with pruning, only complete log lengths (2.1-m increments) should be pruned (partly pruned logs have no added value). Trees should be pruned when branches are as small as possible (i.e., regularly and on time) and in such a way as to not affect tree growth or damage the timber (i.e., using correct technique, without removing too many branches). Finally, no pruned tree should be removed in a pre-commercial thinning (Type 2 *muda*). Excessive or poorly executed pruning is Type 2 *muda*.
Harvesting	✓			Commercial felling, cutting trees into log lengths, and transporting the logs to the roadside all add value. Logs stacked at the roadside have a higher value than standing trees. Large-diameter logs have a significantly higher value than small ones. Silvicultural practices that favour the development of larger log sizes increase value, so silvicultural thinning to progressively remove the smallest trees, rather than the largest trees, adds greater value to the stand.
Transportation	✓			Loading logs onto trucks and transporting them to the mill gate adds value. Logs delivered to the mill gate have higher value than logs stacked at the roadside. Wastefulness associated with delays in transport should be avoided.
Receiving payment			✓	Any delays or costs associated with receiving payment are pure waste and should be eliminated, if possible.

† Type 1 *muda* – necessary but wasteful
‡ Type 2 *muda* – unnecessary and wasteful

The lean system, interestingly, also differentiates between movement and work (Hartman 2015:73), where work involves movement with human innovation. As such, efforts should be made to remove or reduce any unnecessary or unthinking movement of people or products (Type 2 *muda*). Waiting can also be viewed as wasteful, as with delays in scheduling of activities, delays in transporting products to market, or delays in payment. These are all Type 2 *muda* and so should be eliminated, if possible. Correct site selection, appropriate weed control, careful selection of planting materials and on-time thinning all reduce the time to harvest (for the same yield) or increase the yield for the same production time, thereby increasing efficiency.

Here, we can clearly see an opportunity to increase the efficiency of teak agroforestry systems by reducing the labour required for weeding. Manual weeding is not only labour intensive – timing wise, the labour demand for weeding also competes with that of annual crops. In contrast, activities such as thinning and pruning can be done during the dry season, after annual crops have been harvested and before clearing starts for the next crop. The primary factors affecting weeding are the initial success of the burning, the establishment of the companion crop and the inter-tree spacing. A healthy and vigorous annual crop will largely suppress weeds in the first growing season. In the second and subsequent years, weed growth can be reduced by having well-established perennial crops in the alleys, restricting alley width to a maximum of 12 m, and regularly visiting the plot during the growing season so that weeds do not become a serious problem.

Figure 6-5: **Trial participant Mr Sompheng of Pakseng district contemplates which perennial crops he will grow in the alleys between his teak trees, planted along the contour. At that time he was considering growing a perennial grass to feed to his livestock.**

Credit: Nahuel Pachas

Once out of control, weeds are very difficult and labour intensive to control by manual means alone. During the period of our project, mechanical brush cutters imported from China became increasingly common in northern Laos, with one farmer reporting that he could accomplish the equivalent of 10 days of work in one day with a mechanical brush cutter. As the opportunity cost of labour increases, such mechanical alternatives to manual weed control will become more attractive. While the adoption of chemical weed control would also reduce labour requirements, it is less likely due to the perceived risks and a lack of information on the safe use of chemicals in Laos. In the agroforestry trials at Phonsavang village, the additional weed control required under an alley-cropping teak agroforestry system was initially a major concern for many of the participants, but over time they realised the benefits of continued annual incomes from the companion crops, and the impacts of lower stocking rates on improved tree growth rates (compared to nearby woodlots planted at 3 m x 3 m).

For simplicity, while meeting the initial stocking requirements under Implementation Instruction No. 2492/MAF, 2020 (that is, at least 800 trees/ha at planting), we recommend either a 10-m alley width with paired teak rows spaced 2 m x 2 m between/within teak rows giving 833 trees/ha, or a 12-m alley width using triples rows spaced 2.2 m x 2.2 m between trees/rows giving 831 trees/ha. The wider alleys are preferable where households require longer-term production of companion crops. In both cases, to minimise waste, intensive early thinning is required by removing a third to a half of the trees at 4 to 6 years of age. This regime will put the teak trees into a stocking range (400–600 trees/ha) that is most likely to maximise long-term productivity and value (Pachas et al. 2019a, 2019b). Alley widths of 10–12 m, while providing space for the longer-term cultivation of perennial crops, also promote retention of vegetative cover and lead to a reduction in burning. Ribolzi et al. (2017), while not referencing agroforestry systems specifically, suggest educating farmers to use lower stocking regimes for teak planting to reduce soil erosion and stream sedimentation, which have been linked to the expansion of teak planting in upland areas of northern Laos.

There are considerable potential economic benefits to households from the adoption of an alley-cropping agroforestry system with teak in Laos. Nevertheless, households must be fully informed of the potential benefits as well as the necessity of establishing perennial crops to reduce weed control (for example, banana, broom grass, paper mulberry, or perennial grasses for livestock, depending on household requirements) and the additional labour required compared to a traditional *taungya* system. Increased vegetative cover is also likely to yield environmental and community benefits through less soil erosion and better water quality than in monoculture teak woodlots.

References

Cubbage F, Davis RR, Frey GE and Behr DC (2015) 'Financial and economic evaluation guidelines for international forestry projects', in *Tropical forestry handbook*, pp. 2875–2896.

Dieters M, Newby J, Cramb R, Sexton G, McNamara S, Johnson M, Vongphacsouvah S, Sakanphet S, Sodarak H, Singhalath K, Savathvong S, Soukkhy O, Souliyasack B and Midgley D (2014) *Enhancing on-farm incomes through improved silvicultural management of teak in Luang Prabang Province of Lao PDR*, Final report for ACIAR project FST/2004/057, Australian Centre for International Agricultural Research, Canberra, Australia.

Ducourtieux O (2006) 'Is the diversification of shifting cultivation held in high enough esteem in Lao PDR?', *Moussons*, 9–10:61–86.

Hansen P, Sodarak H and Savathvonget S (1997) *Improving livelihoods in the uplands of the Lao PDR*, Technical Report No. 9, Shifting Cultivation Research Subprogramme, Lao Swedish Forestry Programme, Luang Prabang, Lao PDR, [Paper presented to a workshop on Indigenous strategies for intensification of shifting agriculture in Southeast Asia, 3–27 June 1997, Bogor, Indonesia], Cornell University, Ithaca, NY, and International Centre for Research in Agroforestry, Bogor, Indonesia.

Hartman B (2015) *The lean farm: how to minimize waste, increase efficiency, and maximize profits with less work*, Chelsea Green Publishing, Vermont.

Karimuna L, Halim, Ansi A, Marfi WE, Wijayanto T, and Hasanuddin L (2022) 'Growth and yields of two varieties of maizes (*Zea mays* L.) intercropped with peanu (*Arachys hypogaea* L.) applied by bokashi plus fertilizer between the rows of teak tree based agroforestry system', *IOP Conference Series: Earth and Environmental Science*, 951:012041.

Khasanah N, Perdana A, Rahmanullah A, Manurung G, Roshetko J, and van Noordwijk M (2015) 'Intercropping teak (*Tectona grandis*) and maize (*Zea mays*): bioeconomic trade-off analysis of agroforestry management practices in Gunungkidul, West Java', *Agrofrestry Systems*, 89:1019–1033.

Newby JC, Cramb RA, Sakanphet S and McNamara S (2012) 'Smallholder teak and agrarian change in northern Laos', *Small-scale Forestry*, 11:27–46.

Newby J, Cramb R and Sakanphet S (2014) 'Forest transitions and rural livelihoods: multiple pathways of smallholder teak expansion in northern Laos', *Land*, 3:482–503.

Pachas ANA, Sakanphet S, Midgley S and Dieters MJ (2019a) 'Teak (*Tectona grandis*) silviculture and research: applications for smallholders in Lao PDR', *Australian Forestry*, 82(1):94–105

Pachas ANA, Sakanphet S, Soukkhy O, Lao M, Savathvong S, Newby JC, Souliyasack B, Keoboualapha B and Dieters MJ (2019b) 'Initial spacing of teak (*Tectona grandis*) in northern Lao PDR: impacts on the growth of teak and companion crops', *Forest Ecology and Management*, 435:77–88.

Ribolzi O, Evrard O, Huon S, de Rouw A, Silvera N, Latsachack K, Soulileuth B, Lefèvre I, Pierret A, Lacombe G, Sengtaheuanghoung O and Valentin C (2017) 'From shifting cultivation to teak plantation: effect on overland flow and sediment yield in a montane tropical catchment', *Scientific Reports*, 7:3987.

Roder W, Keoboualapha B and Manivanh V (1995) 'Teak (*Tectona grandis*), fruit trees and other perennials used by hill farmers of northern Laos', *Agroforestry Systems*, 29:47-60.

Warner AJ, Jamroenprucksa M and Puangchit L (2016) 'Development and evaluation of teak (*Tectona grandis* L.f.) taper equations in northern Thailand', *Agriculture and Natural Resources*, 50(5):362–367.

Winara A, Fauziyah E, Suhartono, Widiyanto A, Sanudin S, Sudomo, A, Siarudin M, Hani A, Indrajaya Y, Achmad B, Diniyati D, Handayani W, Suhaendah E, Maharani D, Swestiani D, Murniati M, Widyaningsih T, Sulistiadi H, Azmi C and Diana, M (2022) 'Assessing the productivity and socioeconomic feasibility of cocoyam and teak agroforestry for food security', *Sustainability*, 14:11981.

Chapter 7

Exploring opportunities for Indonesia's social forestry agenda

Digby Race, Dede Rohadi, Hugh Stewart, Mark Schmidt, A Muktasam, Achmad Rizal H Bisjoe, Nurhaedah Muin, Wahyudi Isnan, Aneka Prawesti Suka, Silvi Nur Oktalina and Depi Susilawati

Abstract

In this chapter, we provide an overview of the historical role of smallholder forestry in Indonesia, including recent interest and support by government, which reflects the political and social democratisation that has spread across Indonesia since the late-1990s with *reformasi*. More recently, the social forestry agenda in Indonesia has sought to combine efforts to reduce deforestation, expand the supply of commercial timber and encourage smallholders to develop tree plantations as a new enterprise to reduce rural poverty – see, for example, the community plantation forests (*Hutan Tanaman Rakyat,* HTR) scheme within the social forestry program.

We focus on the popular option of growing sengon (*Paraserianthes falcataria*), also known as albizia in other countries, by smallholders in the province of Central Java, and the characteristics of the vibrant value chain that has developed over the past decade. Interestingly, the Indonesian government's effort to curb the illegal harvest and trade in timber led to the development of the timber legality and sustainability verification system, *Sistem Verifikasi Legalitas dan Kelestarian*, previously termed the *Sistem Verifikasi dan Legalitas Kayu*, yet this system has not had the desired outcome of making 'certified' timber more valuable. Instead, the complexity and cost of the verification process has for many forest growers overshadowed any advantages of the system, discouraging some smallholders from becoming more invested in the commercial forestry sector. Furthermore, the use of international certification and labelling, such as the Forest Stewardship Council (FSC), has not always led to the intended increase in demand or greater payments to smallholders for their trees.

As a contrast with the recent emergence of the sengon industry, particularly for smallholders in Java, we also review the centuries-old *phinisi* boat industry based in Bulukumba, South Sulawesi. Given that Indonesia is an archipelago of more than 10,000 islands, having reliable vessels for the trade of valuable cargo has proven vital. On top of this, the *phinisi* industry is experiencing a resurgence due to Indonesia's bustling tourism industry. As each *phinisi* boat is constructed from a variety of native timbers – all carefully selected for exacting needs according to age-old designs – demand for a specific suite of timbers is strong. This happy combination of high demand for a consistent set of timber species has enabled local smallholders to pivot their tree-growing focus to become suppliers for an industry that they trust and understand.

Acknowledgements

The authors acknowledge that much of the information on which this chapter is based is derived from collaborative research with a wide range of colleagues and partners. We are also grateful to the many smallholders, agency and NGO staff, company managers and field staff, and policymakers and program managers who generously participated in the research over many years.

The research was kindly supported by many organisations in Australia and Indonesia, with primary financial support provided by ACIAR for projects FST/2008/030 and FST/2015/040.

Introduction

A successful forestry enterprise takes much more than growing trees, as many project staff and smallholders already know. Reflecting on more than 15 years of research and industry experience to understand the complexity of community-based commercial forestry (CBCF) in Indonesia, we explored the economic, institutional, market, policy, silviculture and social components of smallholder forestry – learning from the past, analysing the present and forecasting the future. In this, we collaborated with partners, tree growers, market brokers and contractors, company owners and field staff, program managers and policymakers, industry analysts and researchers, seeking to bring to bear a wide range of perspectives about what makes CBCF successful in Indonesia.

While the broad aim of our project is to inform how we develop CBCF across Indonesia, the country is so diverse that the opportunities for CBCF vary widely. Our research was mainly conducted in 5 districts with very different characteristics: Bulukumba (South Sulawesi), Gunungkidul (Yogyakarta, Java), Pati (Central Java), South Lampung (Lampung, Sumatera) and Boalemo (Gorontalo, Sulawesi) (Figure 7-1). While the key findings and lessons discussed below reflect the situation of these study sites, they are also relevant to many other parts of Indonesia.

Figure 7-1: Location of study sites in Indonesia

Markets for timber

Demand is strong throughout Java for a range of timber products (for example, sawn boards, veneer, furniture and appearance-grade timber (timber valued for its aesthetic characteristics), although mainly in major centres of economic development and urbanisation – that is, cities with a population of more than 500,000 people. Indonesia has 27 such cities, mostly in Java, Bali and Sumatra. Urbanisation is ongoing, with one estimate indicating that by 2025 more than 67% of Indonesia's population will live in urban areas (World Bank 2010). Even in some regional areas, the population density is high – about 55% (some 150 million) of Indonesia's population of 275 million lives in Java (BPS 2021).

Timber grown by smallholders is mostly sold into local and provincial value chains, whereby smallholders sell their standing trees to local market brokers, who in turn organise the harvesting, transport and preliminary processing, or transport to large integrated processors and manufacturers. Species, timber quality, log dimension and volume mainly determine the price offered to growers, with prices generally satisfying growers if they are living in the vicinity of competitive markets. In rural areas that are remote from centres of economic development, commercial timber production is often not very profitable for smallholders compared to commodity crops (for example, cassava, rice) and cash crops (for example, coffee, rubber).

Smallholders and supporters of CBCF need to analyse the comparative advantage of small-scale forestry in the local context before advocating for the widespread adoption of commercial forestry. While government programs may be able to offset some of the costs and limitations of establishing CBCF as a viable industry within a local context (Permadi et al. 2020), policy interventions need to be carefully designed and implemented so that programs do not distort the market signals that smallholders are likely to receive over the medium to longer term.

A national agenda for 'social forestry'

In Indonesia, the origins of social forestry can be traced back to the Dutch East Indies colonial period around 1873, when the *taungya* system (or *tumpangsari*) of intercropping teak plantation forests with food crops was commonly practised in Java (Hairiah et al. 2003). However, the current iteration of social forestry was introduced more recently. In 2003, at the International Conference on Livelihoods, Forests and Biodiversity, in Bonn, Germany, an Indonesian government representative explained their concept of social forestry (Rohadi 2012). Based on the current regulation (Ministry of Environment and Forestry Regulation No. 9/2021), social forestry is defined as a sustainable forest management system implemented in state forest areas or private forests / customary forests by local communities or customary law communities — as the main actors — to improve welfare, environmental balance and sociocultural dynamics.

There are 5 social forestry schemes, namely:

- Village Forest – *Hutan Desa*
- Community Forest – *Hutan Kemasyarakatan*
- Community Plantation Forest – *Hutan Tanaman Rakyat* (HTR)
- Customary Forest – *Hutan Adat*
- Forestry Partnership – *Kemitraan Kehutanan*.

Community groups that have obtained a social forestry licence have the right to manage a prescribed forest area for 35 years, which can be extended based on the results of an evaluation of their management performance.

When social forestry was formally introduced by the government in 2003, the HTR scheme became its top priority compared to the other schemes. Launched in 2006, the HTR scheme was dedicated to government efforts to alleviate poverty (pro-poor), create new jobs (pro-job) and increase economic growth (pro-growth) (Obidzinski and Dermawan 2010). At its launch, the government set an ambitious target to establish 5.4 million ha of HTR by 2016. The HTR scheme was designed to be established and/or managed by communities, either individually or in groups (through cooperatives), on state forests that were no longer considered productive. Communities who received an HTR licence were granted 60 years' tenure right over state forests, with the possibility of a 35-year extension. The government even provided financial support for HTR establishment in the form of low-interest loans, which were channelled through a public service agency – *Badan Layanan Umum* or BLU – within the then Ministry of Forestry (Herawati 2011).

By the end of 2014, the allocated state forests for social forestry development in Indonesia amounted to 1.4 million ha, with the HTR scheme occupying the largest portion, namely 734,397 ha. Despite the large amount of forest allocated to the HTR scheme, HTR licences issued to the end of 2014 covered only 195,270 ha, or 26% of the allocation. These licences were managed by 330 community groups and 103 cooperatives (Directorate General of Social Forestry and Environmental Partnership 2015). By the latest recorded dataset at the end of 2020, the total established HTR area was 353,861.68 ha (Table 7-1). In comparison, this same dataset recorded the total of granted state forest areas for social forestry at 4.4 million ha, meaning the HTR scheme contributed only about 8% of the total.

Table 7-1: Provincial level details of HTR by the end of 2020 (sorted by area)

Province	Area (ha)	Number of licences issued	Number of granted households
Central Kalimantan	57,640	51	7,555
Jambi	37,730	220	4,084
North Sulawesi	28,104	158	2,408
South Sumatera	22,916	69	3,713
Riau Islands	22,827	6	2,267
Bengkulu	22,177	10	2,219
Lampung	20,159	13	7,489
North Maluku	19,438	4	1,944
Papua	17,180	4	558
North Sumatera	15,891	14	2,699
Southeast Sulawesi	13,156	60	2,884
East Kalimantan	12,942	15	825
Bangka Belitung Islands	10,838	287	1,723
South Sulawesi	7,966	259	1,300
South Kalimantan	7,925	18	656
West Sulawesi	7,730	394	861
Riau	5,669	10	495
Aceh	3,545	6	3,905
West Kalimantan	3,224	33	1,103
East Nusa Tenggara	3,215	17	1,483
Central Sulawesi	3,198	1,100	1,100
North Kalimantan	3,150	34	472
West Nusa Tenggara	3,122	12	2,062
West Sumatera	2,241	91	884
Gorontalo	1,364	63	309
Yogyakarta	327	3	1,228
Bali	177	1	350
Banten	0	0	0
West Java	0	0	0
Central Java	0	0	0
East Java	0	0	0
Maluku	0	0	0
West Papua	0	0	0
Total	353,861	2,952	56,576

Source: Indonesia Ministry of Environment and Forestry (2021)

Others have analysed the various factors that hinder the HTR program's development in Indonesia (Kartodihardjo et al. 2011), which include the following:

- Complex procedures in the HTR licence application process were difficult for farmers to follow. Farmers needed the help of field extension officers in the application process, but their availability was very limited.
- Areas allocated to HTR development were not easy to locate because of the various existing permits within the forest area. Available forest areas for HTR were generally located far from where prospective farmers lived.
- Even though soft loan funds were available through the BLU public service agency, its office was located in Jakarta and there were no branch offices that communities and farmers could easily access. Furthermore, loan distribution by BLU was constrained by the limited number of assessors who evaluate and verify loan proposals put in by communities and farmers.
- Previous bad experiences suffered by farmers in the timber plantation business, especially in timber marketing, discouraged many farmers from investing in HTR business. Also, the business prospects of timber plantations often have difficulty competing economically with other commercial crop plantations, such as rubber and oil palm.

Strong prospects for teak and sengon

Smallholders typically view CBCF as a relatively passive undertaking compared to most agricultural enterprises, giving little effort to pruning and thinning trees as a forest grows. For most smallholders, any motivation to plant trees competes with their interest in planting short-term food crops to provide the necessary cash flow to support a farming family's daily needs. Moreover, a poor grasp of market dynamics often sees smallholders sell their trees when in need, rather than at the optimum time for financial returns.

A study in the Pati district, Central Java, evaluated the profitability of timber production for sengon (*Paraserianthes falcataria*) and teak (*Tectona grandis*) plantations grown by smallholders. Details of the silvicultural systems, timber yields, cash flows, and financial analysis are provided in related publications (see Stewart et al. 2020, 2021). Financial analysis (Table 7-2) indicated that, in each of the 3 options tested – sengon thinned, teak thinned and teak not thinned – the internal rate of return (IRR) exceeded the discount rate, making all 3 profitable investments. As to which option offered the best financial alternative, the analysis sought to find the option that yielded the highest present value at the investor's cost of capital (Gansner and Larsen 1969). Accordingly, the analysis indicated that a 30% increase in income could be made by choosing the option to invest in teak (US$3,584/ha versus US$2,746/ha), as expressed by land expectation value (LEV). The results were sensitive to the discount rate and, at 4%, teak was clearly the most profitable investment, whereas at 12% the profitably of teak and sengon was similar, as indicated by LEV. These results illustrated the utility of calculating LEV and testing its sensitivity to the discount rate when evaluating alternative forestry investments that have markedly different rotation periods.

The analysis showed the benefits of thinning teak plantations – the net present value (NPV) of an unthinned stand of trees was only half that of a thinned stand (thinned at ages 6 and 12 years), which provides a strong financial incentive for smallholders to invest in better silviculture.

Table 7-2: Financial outcomes for smallholder sengon and teak plantations in the Pati district, Central Java

Parameter	Sengon (thinned)	Teak (thinned)	Teak (not thinned)
Discount rate (real %)	8	8	8
Rotation period (years)	6	20	20
Total volume harvested (m^3/ha)	135	149	136
MAI (m^3/ha/year)	22.5	7.4	6.8
NPV (US$/ha)	1,015	2,815	1,420
LEV (US$/ha)	2,746	3,584	1,807
IRR (%)	20	15	12
Cash outlay (PV basis) (US$/ha)	1,392	1,634	1,634
Cash outlay excluding labour (US$/ha)	623	491	491
Return to labour (US$/day)	8.3	12.3	8.0

MAI = mean annual increment of timber production; NPV = net present value; LEV = land expectation value (the NPV for an infinite sequence of identical rotations, which is useful to compare forestry investments of unequal duration (Herbohn 2002)); IRR = internal rate of return; PV = present value

Source: Stewart et al. 2020, 2021

In the Pati study, labour accounted for about 45% of the establishment costs and all the annual maintenance costs. In a sensitivity analysis, returns to labour (the labour cost at which the NPV is zero) were estimated to be US$8.3/day for sengon and US$12.3/day for teak. These rates exceeded the minimum wage for all workers at a district level, implying that labour used in smallholder forestry could generate, over the long term, earnings that would be competitive with agricultural work and with external employment options.

Many smallholders do not fully understand the cash outlays required to successfully undertake forestry, such as the costs of plantation establishment and ongoing maintenance. Smallholders are accustomed to planting annual crops where negative cash flows from establishment and maintenance costs are usually resolved within a year at the end of each harvest. Investment in forestry, on the other hand, requires a smallholder to carry a negative cash position for a relatively long period. This became evident when charting the cumulative present value of a smallholder's cash position for an investment in a sengon or teak plantation (Figure 7-2).

Given that most smallholders do not factor their own labour into their enterprises, the chart also shows the cash positions for smallholders that internalise their labour alongside those that use hired labour (the base case for the financial analysis). Smallholders who use their own labour to establish and maintain their forests have substantially less cash outlays than those who use hired labour. Nevertheless, for sengon, smallholders are subject to a negative cash position until the final harvest at 6 years under both labour scenarios. For teak, however, smallholders who internalise their labour realise a positive cash position at 12 years due to the revenue from the thinning, whereas those who use hired labour have to wait until the final harvest at age 20 years to be cash positive.

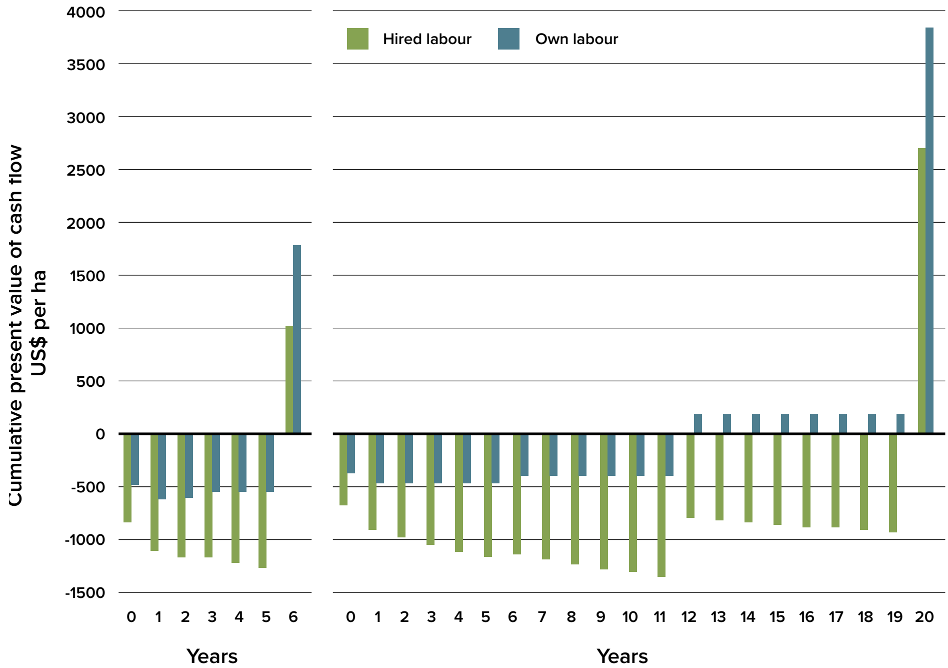

Figure 7-2: **Cumulative cash flows (on a present value basis) for a smallholder sengon plantation (left graph) and teak plantation using hired labour versus own labour (right graph)**

Forestry projects are long-term investments that are subject to many risks not explicitly factored into these analyses. Such risks include:

- biological and physical risks (for example, drought, fire, flood other climatic extremes, insect and pest damage, and disease)
- real and nominal movements in costs relating to growing, harvesting, and hauling logs (the analyses assumed log markets were located within 100–150 km of plantations) and in prices of logs
- changes in government legislation that affect the viability or profitability of the investment or the right to harvest the timber products
- sovereign risks associated with government policy on export of logs and products.

Results from this research illustrate how contemporary forestry practices can prove profitable for smallholders in Indonesia. Sengon and teak production presents an opportunity for smallholders to participate in an industry with a positive outlook. Demand for the timber is buoyant, Indonesia has a culture of smallholder forestry, and the government is placing a priority on facilitating smallholders' involvement in commercial timber production. The 'community plantation forestry' (HTR) scheme offers a unique opportunity to develop commercial sengon and teak forests on state-owned land with a low opportunity cost, underpinned by government policy, commitment and resources. Professional forestry management and coordination could be applied to implement the HTR scheme at scale. This approach could create a necessary shift in momentum that would directly enhance regional economic development as smallholder commercial forestry became more reliable and sustainable. Moreover, it could create a viable pathway for the Indonesian government to achieve its ambitious targets for social forestry.

Commercial markets for certified timber

Certification proving timber's legal and sustainable sourcing has become an increasing requirement for international trade (for example, FSC certification). We found, however, that this has generally not led to expanded or new markets for smallholder forestry, with the cost of the certification process usually exceeding any additional increase in timber prices. While larger non-government organisations (NGOs) or companies have funded forest certification for smallholders, these initiatives are usually viewed in terms of achieving longer-term targets or meeting 'social licence' goals. Consequently, there is little economic incentive for smallholders to undertake FSC certification independently. Joining larger, district-wide initiatives or growing trees under contract to larger projects or companies appears the most feasible route to certification (Rohadi et al. 2020). Even then, certification will need to add value to the whole value chain for people at all stages to invest in the verification process.

In 2009, Indonesia introduced the *Sistem Verifikasi Legalitas dan Kelestarian* (SVLK) to ensure only timber from legal sources is processed and exported to markets such as in the European Union. Smallholders are in a position to easily self-declare the legal provenance of their trees, so the timber can then be sold to SVLK-certified processors and then exported. Research has found, however, that the high cost of verifying timber along an extended value chain, particularly for infrequent and small timber supplies (for example, from smallholders) was difficult for CBCF to sustain (Susilawati et al. 2019). The research also found that when the value chain includes timber from a wide range of sources, as often occurs with CBCF, certified timber can be 'blended' with uncertified timber, masking the origins of timber in a manufactured product.

Figure 7-3: Naturally grown sengon is taken for further processing at a sawmill at Rumbia, Boalemo, Sulawesi.

Credit: A Muktasam

Case study: Forest certification experience of Trees4Trees in Pati, Central Java

A forest certification project was designed in 2010 to help farmers in Pati, Central Java, gain more from their smallholder forests and improve their channels to market. It initially focused on the sengon tree species because it had the least fragmented timber market and the greatest demand from farmers because of its short rotation with frequent payouts (4–5 years). The project was led by Indonesia-based NGO Trees4Trees, which acted as the FSC group manager and farmer trainer. The local farmers, who expressed a strong preference for growing sengon, enthusiastically supported the project.

At the outset, an agreement was reached with a local sengon processor who intended to start selling FSC-certified plywood in their European market. The initial agreement and business plan called for 1,000 m^3 of certified timber production per month as the minimum break-even volume, ramping up to more than 10,000 m^3 per month as the market developed. The factory owners believed that they could expect a 10% price premium for their certified products in the marketplace. Part of this premium was to be paid as an incentive to the farmers to ensure they would attend the necessary training as well as follow the forest management and bookkeeping requirements of certification. The project recruited farmers to join the training and process of certification. While the farmers received no monetary incentive at this stage, monitoring of the local market indicated that farmers were receiving about 10% more for their timber through the Trees4Trees process of transparently calculating the wood volume, grade and prices, than they would have received from the traditional local broker's approach of offering a lump sum for the entire stand of trees.

The initial strategy involved harvesting non-certified wood to develop the supply chain throughput. When the forests obtained certification, it was expected the farmers would become eligible for an extra incentive payment on their timber. By 2013, forests managed by 36 villages were certified for FSC Controlled Wood, and 6 villages had started harvesting certified wood, receiving an incentive of US$10.60/$m^3$ (Indonesian rupiah IDR100,000/m^3) on their wood sales. In the years 2011 through 2015, the project certified a total of 18,363 ha of forestland in 36 villages, for 625 farmers. The project reached the production volume target of 1,000 m^3 in only 2 months during 2014. Production shortfalls in 2011 were mainly due to start-up and harvesting bottlenecks. In 2012–2014, the shortfalls were the result of limited demand from the factory. In 2015, no loads of certified timber were accepted by the factory and the management indicated that in future they expected to reduce processing to an average of 100 m^3 per month due to low acceptance of the 10% price premium for certified products in the marketplace. At that point the project was terminated as it was economically unviable.

Lessons learned:

- The wholesale and retail markets in commodity wood products were not willing to pay a premium for certified wood (in the period 2011–2015). Market research is crucial.
- The cost of FSC Controlled Wood certification for smallholder forests (less than one ha) under the FSC Group Certification program was, on average, US$27/ha. This contrasts with the US$4–US$6/ha certification cost for large-scale forests at the time. The ongoing cost of maintaining certification was US$3–US$5/ha per period for smallholders, but less than US$1/ha for large-scale forests.
- Smallholders were not willing to share any part of the timber sales price premium with the group manager to cover the implementation and operational costs of the program.
- A major entry barrier for smallholders concerns the logistics around the timber accepted by their local factory. Each factory uses a specific range of timber dimension and grades and will not accept or pay less than market price for grades outside their range. A sorting depot is needed to optimise timber selling prices and minimise transport costs, and this requires a significant capital investment, often outside the means of local farming communities.

Case study: Lessons from the SVLK about the effectiveness of timber certification

In their analysis of the SVLK in Indonesia, Susilawati et al. (2019) found both specific and systemic issues with its design and implementation. The specific issues related to non-compliance by smallholders, market brokers, sawmills and wood panel manufacturers. In a case study of smallholder value chains in East Java, only a small number of smallholders and primary processors were found to comply with SVLK requirements.

There were several systemic issues:

- While a Supplier's Declaration of Conformity (*Deklarasi Kesesuaian Pemasok*) is allowed as a substitute for SVLK for certain small-scale actors, market brokers and wood panel manufacturers did not provide or require a declaration (origin of wood) for all the logs they bought from smallholders (Susilawati et al. 2019).
- SVLK does not specifically require the separation of verified and unverified wood, and manufacturers are able to label as SVLK-verified finished products that are a mix of verified and unverified wood.
- There is a lack of monitoring and verification of SVLK compliance in smallholder value chains.

The concept of 'smart regulation' (Gunningham and Sinclair 2017:135) suggests that SVLK implementation can be improved by drawing appropriately on the respective roles of both state and non-state actors. In the above case of CBCF, state actors could better inform, engage and facilitate smallholders' participation in more formalised wood production and trading. This would require greater capacity building, and financial and technical assistance, to enable smallholders to achieve and maintain SVLK verification, including through correct use of the self-declaration mechanism (the grower's 'declaration of conformity' was developed by the Indonesian Ministry of Environment and Forestry to simplify the regulations for trading community-grown timber and to reduce the transaction costs for smallholders).

The state should also strengthen collaboration and coordination within and between the relevant ministries (that is, Ministry of Industry and Ministry of Trade) and subnational governments; continue the development of an integrated wood traceability system; and invest more in law enforcement at national and subnational levels. In addition, the extent and quality of independent monitoring provided by non-state actors could be increased to lessen the risk of 'greenwashing' uncertified wood into certified products. These strategies would mitigate the inherent weaknesses of self-reporting instruments in SVLK. A more recent analysis of a case study elsewhere in Indonesia found that positive partnerships between large-scale wood processors and market brokers could foster a higher standard of compliance with SVLK (Susilawati and Kanowski 2021).

All actors in upstream and downstream chains should promote SVLK in both domestic and international markets. The state should provide incentive mechanisms to foster small-scale actors' compliance, such as access to exhibitions of wood-based products, expanded networks to international buyers, green public procurement, and tax deductions. Large-scale wood processors could be encouraged to build SVLK-compliant value-chain partnerships with small-scale wood suppliers. In this case, the companies can pay verification costs and provide technical aid to smallholders. Private actors such as business associations and NGOs could also more proactively facilitate small-scale actors to meet legal requirements through localised knowledge transfer (for example, *Klinik SVLK*, initiated by ASMINDO[12] and ARuPA[13]). Finally, educating market brokers in smallholder value chains is crucial, particularly the appropriate use of self-declaration within SVLK, as highlighted by Susilawati and Kanowski (2021) in their case study of a large-scale wood processor that has effective partnerships with market brokers and, so, fosters legality compliance.

12 ASMINDO – *Asosiasi Pengusaha Mebel Indonesia* (Indonesian Furniture Industry and Handicraft Association)

13 ARuPA – *Aliansi Relawan untuk Penyelamatan Alam* (Volunteers Alliance for Saving Nature)

Smallholders attaining knowledge and skills

A poor understanding of silviculture (tree management) by smallholders is frequently reported to undermine the potential commercial returns from CBCF. To address this gap in knowledge and skills, we adapted the Master TreeGrower (MTG) training course to the Indonesian context and have delivered 21 courses since 2014 (Muktasam et al. 2021), with additional courses self-funded and delivered by Indonesian agencies. Over 400 smallholders have undertaken the innovative MTG training, which focuses on growers' understanding of the local marketplace, tree management and measurement, how silviculture links to prices, risk management, agroforestry, and non-timber forest products (Reid 2017). See **chapter 13** for a more detailed discussion of the MTG training program. A feature of the farmer-centred training of the MTG course is that it takes growers to the marketplace so they can hear, see and understand the dynamics of how timber is priced at the 'finished' end of the value chain. Post-training evaluation indicated that more than 50% of MTG course participants in Indonesia have changed the way they manage their forests and have planted additional trees with more confidence in their silviculture and commercial value (Muktasam et al. 2019).

Farmer-to-farmer mentoring

Participants in the Indonesian MTG training courses were encouraged to share the knowledge, skills and experiences they had gained with their family members, neighbours and reference group members. Evaluation of the MTG training courses found that most farmers who participated in the MTG training courses shared what they had learnt via the farmer-to-farmer mentoring initiative that was part of the MTG course. They even helped with tree management, and demonstrated how to prune and thin trees, for example. In Pati, the 17 enrolled participants from 12 villages facilitated learning for their family and friends during the MTG field management practices, with an additional 10 farmers from Plaosan village and 15 farmers from Gulangpongge village attending (Figure 7-4).

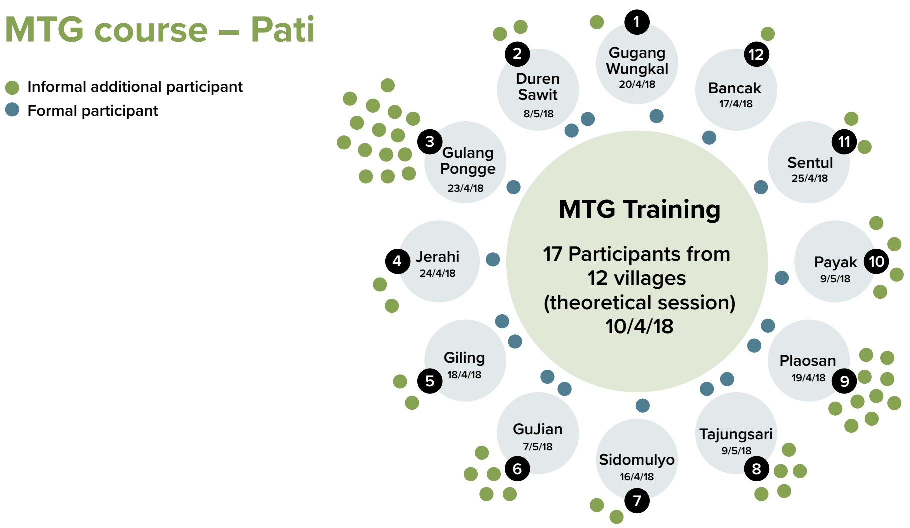

Figure 7-4: Influence of the MTG training courses in Pati in 2018. While 17 participants were registered, an additional 10 farmers from Plaosan village and 15 farmers from Gulangpongge village were motivated to attend field management practices.

Figure 7-5: **Additional farmers from Plaosan village were motivated to join those enrolled (green shirts) in the MTG training course in Pati, Indonesia.**

Credit: A Muktasam

To build more awareness of the interests and needs of women, we adapted several MTG courses to suit them (Figure 7-6). Adopting a gender-sensitive approach resulted in equal numbers of men and women undertaking the MTG training and gave more women the confidence to share their experience with CBCF among their networks of family and friends (Harsoyo et al. 2020) (see Box 7-1).

Box 7-1: **Designing an effective approach to engage farming women in forestry training – 5 tips**

- Understand women's farming capabilities, needs and interests.
- Co-design training courses (approach and content) with representatives of local women's farming groups.
- Minimise barriers for women's participation. For example, conduct training within or near their village, offer training at a convenient time of the day/week/season for potential participants, provide refreshments and meals, ensure appropriate washrooms are available.
- Involve local women in delivering the training and translating the information into the local context. Encourage women to share their experience and knowledge of forestry.
- Support experienced women to mentor other farmers in their village.

Raising smallholders' capacity through the MTG training courses was also appreciated by the private sector, with businesses anticipating that it will translate into producing timber of higher quality that is more likely to meet industry specifications (Suka et al. 2020).

Figure 7-6: Women and men participating in Master TreeGrower training courses, Indonesia

As a result of the course evaluation, to improve farm management practices we adapted the farmer-to-farmer mentoring approach to promote further changes in farmers' knowledge, skills and attitudes. MTG participants learned about markets, tree measurement, and tree and farm management. Indonesian farmers, researchers and policymakers learned from a study tour to the state of Victoria in Australia, where the Otway Agroforestry Network shared 5 criteria for effective mentoring, based on their experience. Mentors need to:

- own land within the same region as the farmers they are mentoring
- have personal experience in growing their own trees
- have completed an MTG course
- be willing to share their experience with other landholders
- have the time and communication skills to participate in the program. (Muktasam et al. 2020)

The farmer-to-farmer mentoring trial in Bulukumba revealed that the mentoring helped promote further community and farmer learning (Figure 7-7). By observing mentors undertaking tree and farm management, the local farmers were prompted to seek help and explanations from the trained mentors. Farmers, it was found, were more likely to value information from mentors with whom they have a lot in common. And, as a bonus, when farmers act as mentors they can complement and strengthen existing extension (advisory) approaches and programs (Muktasam et al. 2020).

Strengthening the social networks of smallholders not only raised their level of knowledge about CBCF, but also gave them more realistic expectations of what constituted a fair price for their produce. A cohesive local community makes it easier for smallholders to assemble a critical mass of tree produce to attract interest from major processors. This can potentially lead to greater financial returns, more investment in building the capacity of local networks of smallholders, and improved marketplace linkage. Scaling up can be particularly important for remote rural communities with limited social networks.

Figure 7-7: **Diagram of the social connections developed by the farmer-to-farmer mentoring process in Bulukumba. The 3 mentors (left) helped the other farmers on their own farms.**

Credit: A Muktasam

Smallholders diversifying enterprises

The economic development of Indonesia is leading to greater urbanisation and city-based employment. Even among smallholders who identify as farmers, many earn most of their household's income from off-farm employment and enterprises (Race et al. 2019). We surveyed representative families in study sites in Bulukumba, Gunungkidul and Pati (8 villages), recording the composition of annual income in 2013, 2017 and 2020 (n = 240). The survey revealed that across the sampled households, 56% of income was derived from off-farm sources (for example, through employment as labourers or in small enterprises). Even in locations where agriculture is still the dominant source of household income, such as in Boalemo and South Lampung (in Gorontalo and Lampung provinces, respectively), an increasing proportion of income was derived from off-farm sources during 2018 and 2020 (n = 60) (Race et al. 2021). Agroforestry comprised about 29% and commodity agricultural crops comprised 14% of household income – less than 50% combined (Race et al. 2021) (Figure 7-8).

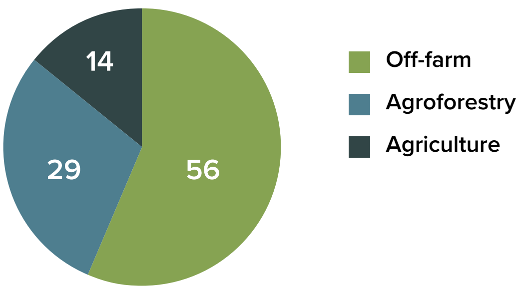

Figure 7-8: **A survey of representative households (n = 240) in Bulukumba, Gunungkidul and Pati (8 villages) found that 56% of income was derived from off-farm sources (Race et al. 2022).**

Agroforestry was listed as a prominent land use for smallholders across the range of 'low', 'medium' and 'high' wealth categories (Figure 7-9), indicating its broad appeal for many smallholder families.

Where vibrant local markets exist for timber and non-timber products, agroforestry is an appealing option for the full range of smallholders. It allows them to passively accrue wealth as their trees grow until such time as the family chooses to make a large purchase (for example, health care, school fees, large family celebrations). Some smallholders refer to their trees as a 'living savings account' (Irawanti et al. 2017).

Growing trees requires low capital investment and relatively little labour input, compared to other more intensive crops (for example, coffee). Consequently, integrating a small number of sengon and teak trees into a farm is seen by smallholders as an easy option. Even when adopting the recommended silviculture, smallholders can do much of the work themselves using existing farm equipment (such as a hand saw) at convenient times.

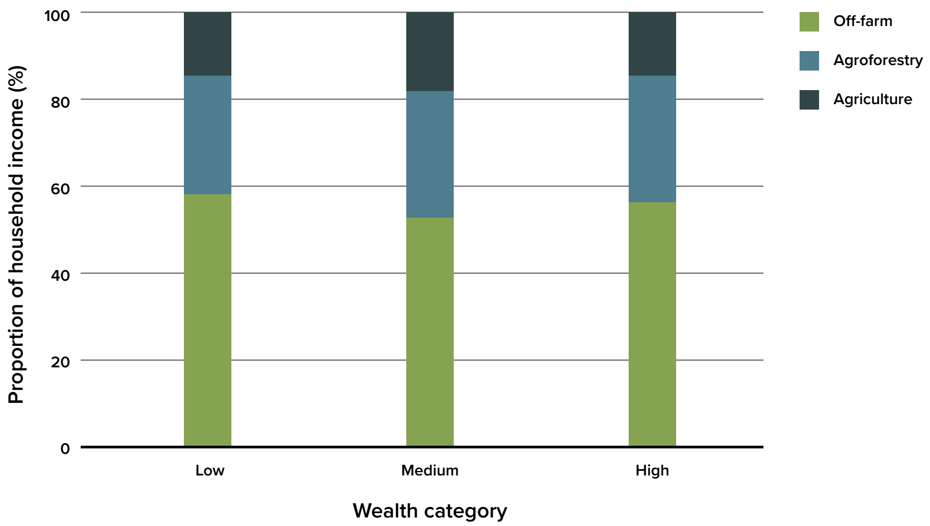

Figure 7-9: **Relative average proportion (%) of household income from different sources for 'wealth' categories, based on a survey of representative households (n = 240) in Bulukumba, Gunungkidul and Pati (8 villages) (Race et al. 2022)**

Policy context

Government faces a myriad of challenges when seeking to optimise economic development across a highly diverse country and population. Achieving the desired outcomes from a national policy in any given situation is a complex task (Wibowo et al. 2013). Indonesia, with its 3 tiers of government, faces an even more challenging task in implementing consistent and effective policy. The President of Indonesia has re-committed to establishing 12.7 million ha of social forestry across Indonesia on degraded forest land owned by the state. While this is a well-intentioned and well-supported policy goal, the social forestry program has not always been able to achieve its annual target.

A major challenge for policymakers is ensuring the policy pathway has the capacity and resources so that the social forestry program is understood and effectively delivered in diverse local settings (Wahyudiyati et al. 2019). As well as building the capacity of communities of smallholders, for example, agencies, NGOs and companies also need the capacity to analyse and compare the relative value of CBCF compared to other agricultural and development opportunities (Wibowo et al. 2019). Implementing national programs across Indonesia's 34 provinces with a degree of consistency creates some efficiency, yet there also needs to be scope for adapting national programs to the local context and local needs if the social forestry program is to become a viable model. A supportive policy environment is required in all tiers of government, all the way down to village regulations (*peraturan desa*).

Whereas the social forestry program was initiated by government, its success will be largely determined by whether or not millions of smallholders can develop CBCF into a profitable enterprise that is supported by a competitive network of local and provincial processors and manufacturers. The financial analysis of sengon and teak (presented above) indicates that integrated CBCF on a large scale is feasible, at least in Central Java where the data was derived (Stewart et al. 2020).

Clear foresight

Indonesia's economy is dynamic and expanding, but, like any country, it is not isolated from global economic shocks and challenges. We looked ahead to the future of smallholder forestry in 2030 with a strategic analysis identifying key influences and markets for smallholders (Robins and Kanowski 2019). While the smallholders we interviewed focused on likely ways to improve their family's wellbeing (which may not include growing trees), staff of timber processing companies focused on ways to encourage smallholders to grow more wood, provincial agency staff focused on ways forestry could support regional development, and national policymakers focused on incentives that could encourage smallholders to establish and manage large areas of forests.

The overall demand for timber is anticipated to increase, but increased demand may not necessarily translate into profitable opportunities for smallholders if much of the demand is for low-value fibre that is grown and processed on a large scale. The best opportunities for smallholders are likely to be in growing trees for local and provincial markets with short value chains in the major centres of economic development, and for small niche markets (for example, construction of *phinisi* boats and certified furniture) (Figure 7-10).

Figure 7-10: Construction of *phinisi* boats relies heavily on the supply of timber from smallholder forests.

Credit: Gib Wettenhall

Case study: The traditional *phinisi* boat-building industry in Bulukumba, South Sulawesi

The *phinisi* is a traditional Indonesian sailing boat, originating from the Bugis and Makassar peoples in Bulukumba, South Sulawesi Province. Built since the 14th century, the *phinisi* was reportedly first made by the crown prince of the kingdom of Luwu (in South Sulawesi) for a voyage to China. On the way back, an accident split the boat into 3 parts, which were stranded in the coastal villages of Ara, Tanah Beru and Tanah Lemo in the regency of Bulukumba. The village communities managed to reassemble the broken boat. Their knowledge has been passed on from generation to generation, and Bulukumba is now commonly known as *Tana Panrita Lopi* – the Land of Boat Builders.

A unique aspect of *phinisi* boat building is the reliance on a *punggawa*, who leads the design and construction, without referring to written plans or records, including for material amounts, size and design details.

At first, the *phinisi* boat industry sourced materials and markets locally only. In recent years, increasing demand and improvements in technology have resulted in *phinisi* builders varying the range of boat sizes on offer and taking orders from foreign investors. The toughness of the boat design has been tested on several international voyages, including from Jakarta to Vancouver, Canada, in 1986 and to Japan in 1992, for cultural promotion; and in retracing ancestral journeys from Makassar to northern Australia in 1988 and to Madagascar in 1991.

In 2016, the Bulukumba Industry and Trade Office recorded 38 separate businesses building *phinisi* boats. The number of *phinisi* boats made in a year varies depending on orders. Making a *phinisi* requires from 4 to 40 workers depending on the size of the boat. A medium-sized *phinisi* with a length of 10–20 m and a width of 4–8 m requires 5 to 10 workers, led by a *punggawa*.

Most of the main raw timber supplied for the *phinisi* industry in Bulukumba comes from community forests, both from Bulukumba and from outside the region. The types of wood used are ironwood (*Eusideroxylon zwageri*), bitti (*Vitex cofassus*), teak (*Tectona grandis*), nyamplung (*Callopyllum inophyllum*), gmelina (*Gmelina arborea*) and mixed timber. To build a *phinisi* with a load capacity of 35 tonnes, about 50 m^3 of wood is needed.

The *phinisi* building industry is not immune from the problems and constraints related to demand and supply. Some of the challenges boat builders face are limited raw wood materials from community forests, lack of a patent for the *phinisi* boat design, interference from foreign buyers, and limited technology and business management skills. Also, the change in government agency responsible for oversight and support of community-based forestry, from the district to the provincial level, has seen less attention paid to CBCF, including to ensuring the ongoing supply of wood needed for the phinisi industry.

For the Bontobahari people in Bulukumba, as *phinisi* craftspeople their culture is not only a source of livelihood, but also a means of preserving ancestral culture. That, in the end, is the driving force as to why the boat industry still thrives to this day.

Making community-based commercial forestry work in Indonesia

- The economic dynamics that directly influence the profitability of smallholder forestry mostly operate at local and provincial levels. Creating vibrant business ‘hubs’ for CBCF at these levels – that smallholders can afford to access – is vital. Professional forestry management and coordination could be provided through such hubs to implement the HTR program at scale. Hubs need to consist of multiple value chains for the range of timber products grown by smallholders (for example, from low to high grade timber).
- These hubs should support smallholders and field staff in increasing their knowledge and skills, such as through the farmer-centred MTG training courses that start by taking growers to the marketplace – a ‘market-first’ approach. Raising the knowledge and skills of smallholder forestry will flow on to the future supply of timber desired by markets, so government support to facilitate advisory or extension services for smallholders is vital. As an example of government support, the Bulukumba Environment and Forestry office has been funding MTG training courses for several years for interested villagers.
- The government agencies need to be well connected and streamlined for efficient administration, coordination of support activities and effective regulatory oversight of the timber value chain – from growing to harvesting, transporting, processing and manufacturing, to export or retail. A one-stop office (for example, the regency office) where all the permits and documentation for CBCF can be administered, completed and authorised, and readily accessed by smallholders, would be best. It could also be a place to demonstrate or support smallholder forestry, such as training for smallholders in establishing their own tree nursery.
- Introducing timber ‘standards’ (product specifications and prices expressed or translated into measurements and terms familiar to farmers) that are widely accepted and understood will help consolidate the value chain, so that each actor is better informed about the quality and prices of the product as it moves along the value chain.
- Ensuring CBCF is a profitable enterprise for smallholders will motivate them to replant after they have harvested trees and encourage their farming neighbours to also invest in CBCF. If this process is replicated at scale, we could see CBCF drive reforestation across Indonesia and achieve the President’s ambition of having 12.7 million ha of degraded rural land transformed into different types of forests, including for productive (permitted harvests) and protected (conservation orientated) forestry.
- While most of our project’s research focused on timber, CBCF also includes a range of non-timber forest products (for example, bark, medicinal herbs, fruits and seeds, honey) and, increasingly, novel markets for environmental services (for example, ecotourism, carbon sequestration, biodiversity). Expanding the focus of CBCF beyond timber will open new markets and appeal to a wider range of potential investors – from smallholders to small and large businesses, government and private organisations, domestic and global markets. An exciting era for CBCF awaits!

References

BPS (Badan Pusat Statistik) (2021) *Portrait of 2020 population census*, BPS, Jakarta.

Directorate General of Social Forestry and Environmental Partnership (2015) *Strategic Planning 2015-2019*, Directorate General of Social Forestry and Environmental Partnership, Ministry of Environment and Forestry, Jakarta.

Gansner DA and Larsen DN (1969) *Pitfalls of using internal rate of return to rank investments in forestry*, Research Note NE-106, Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA, US.

Gunningham N and Sinclair D (2017) 'Smart regulation', in Drahos P (ed) *Regulatory theory: foundations and application*, ANU Press, Canberra, Australia, pp. 133–148.

Hairiah K, Sardjono MA and Sabarnurdin S (2003) *Pengantar agroforestri: bahan ajaran agroforestri 1*, World Agroforestry Centre, Bogor, Indonesia.

Harsoyo, Oktalina SN, Permadi DB, Hardiyanto EB, Wiyono and Race D (2020) *Empowering women in community-based commercial forestry through Master TreeGrower (MTG) training*, Project research report, University of Gadjah Mada, Yogyakarta, Indonesia.

Herawati T (2011) *Community forest estate: policy process analysis and design of policy conceptual model* [doctoral thesis], Post Graduate School, IPB University, Bogor, Indonesia.

Herbohn JL (2002) 'Using financial analysis techniques in forestry research', in Harrison S, Herbohn J, Mangaoang E and Vanclay J (eds) *Socio-economic research methods in forestry: a training manual*, pp. 177–190, Rainforest Cooperative Research Centre, James Cook University, Cairns, Australia.

Kartodihardjo H, Nugroho B, Rohadi D, Suharjito D and Dermawan A (2011) *Community plantation forests in Indonesia: challenges and policy recommendations*, Info Brief No. 42, Center for International Forestry Research, Bogor, Indonesia.

Ministry of Environment and Forestry (2021) *Statistic 2020*, Ministry of Environment and Forestry, Jakarta, Indonesia.

Muktasam A, Reid R, Race D, Wakka AK, Oktalina SN, Agusman, Herawati T and Bisjoe ARH (2019) 'Enhancing the knowledge and skills of smallholders to adopt market-oriented tree management practices: lessons from Master TreeGrower training courses in Indonesia', *Australian Forestry*, 82:4–13.

Muktasam A, Reid R, Wakka AK and Race D (2020) *Evaluation of the farmer-to-farmer mentoring trial*, Project research report, Mataram University, Indonesia.

Muktasam A, Reid R, Race D, Kadir AK, Bisjoe ARH, Darisman A, Silvia D, Oktalina SN, Wiyono, Kuncoro, Sugeng, Rohadi D and Herawati T (2021) *Evaluation of the Master TreeGrower courses in Indonesia: Phase 2, 2018 – 2020*, Project research report, Mataram University, Indonesia.

Obidzinski K and Dermawan A (2010) 'Smallholder timber plantation development in Indonesia: what is preventing progress?', *International Forestry Review*, 12(4):339–348.

Permadi DB, Muin N, Bisjoe ARH, Purwanti R, Hayati N, Hapsari E, Silvia D, Darisman A, Oktalina SN, Hardiyanto EB and Race D (2020) *Adoption of tree farming by smallholders in Pati and Bulukumba, Indonesia*, Project research report, University of Gadjah Mada, Indonesia.

Race D, Suka AP, Irawanti S, Surati, Oktalina SN, Bisjoe ARH, Muin N, Purwanti R and Sumirat B (2019) 'Smallholder forestry: the role of commercial forestry in rural livelihoods in Indonesia', *International Forestry Review*, 21(2):225–237.

Race D, Suka AP, Surati, Kurniasari DR, Sumirat B, Herawati T, Bisjoe ARH, Muin N, Purwanti R, Hapsari E, Oktalina SN and KC B (2021) *Economic and social dimensions of smallholders' household: a survey to understand the livelihood context for commercial smallholder forestry in Indonesia*, Project research report, University of the Sunshine Coast, Queensland, Australia.

Race D, Suka AP, Oktalina SN, Bisjoe ARH, Muin N and Arianti ND (2022) 'Modern smallholders: creating diversified livelihoods and landscapes in Indonesia', *Small-scale Forestry*, 21:203–227.

Robins L and Kanowski P (2019) 'Megatrends affecting smallholder forestry in Indonesia to the year 2030', *International Forestry Review*, 21(3):350–371.

Rohadi D (2012) *Analysis of farmer's perceptions and strategies in smallholder timber plantation business (Case studies of smallholder timber plantations at Gunungkidul District, Special Province of Yogyakarta and Tanah Laut District, Province of South Kalimantan*) [doctoral thesis], Post Graduate School, IPB University, Bogor, Indonesia.

Rohadi D, Herawati T and Stewart H (2019) *Status of forest and timber certification for smallholder growers in Indonesia*, Project research report, Forestry and Environmental Research, Development and Innovation Agency (FOERDIA), Ministry of Environment and Forestry, Bogor, Indonesia.

Reid R (2017) 'Developing farmer and community capacity in Agroforestry: is the Australian Master TreeGrower program transferable to other countries?', *Agroforestry Systems*, 91:847–865.

Stewart H, Rohadi D, Schmidt DM, Race D, Novita DA, Silvia D and Darisman A (2020) *Financial models for smallholder sengon and teak plantings in the Pati district, Indonesia*, report for ACIAR project FST/2015/040 'Enhancing community-based commercial forestry in Indonesia', Australian Centre for International Agricultural Research, Canberra, Australia.

Stewart H, Race D, Rohadi D and Schmidt DM (2021) 'Growth and profitability of smallholder sengon and teak plantations in the Pati district, Indonesia', *Forest Policy and Economics*, 130:102359, doi:10.1016/j.forpol.2021.102539.

Suka AP, Bisjoe ARH, Muin N, Oktalina SN, Darisman A and Arianti ND (2020) *Private sector and stakeholder links for enhancing community-based commercial forestry in Indonesia*, Project research report, Forestry and Environmental Research, Development and Innovation Agency (FOERDIA), Ministry of Environment and Forestry, Bogor, Indonesia.

Susilawati D and Kanowski PJ (2021) 'Sustainability certification and legality verification in Indonesian natural forest-based wood products value chains', *International Forestry Review,* 23:365–391, doi:10.1505/146554821833992839.

Susilawati D, Kanowski P, Setyowati AB, Resosudarmo IAP and Race D (2019) 'Compliance of smallholder timber value chains in East Java with Indonesia's timber legality verification system', *Forest Policy and Economics*, 102:41–50.

Wahyudiyati KT, Kuniasari DR, Wibowo LR and Race D (2019) *Fostering the community plantation forest (HTR) program in Lampung and Gorontalo, Indonesia*, Project research report, Forestry and Environmental Research, Development and Innovation Agency (FOERDIA), Ministry of Environment and Forestry, Bogor, Indonesia.

Wibowo LR, Race D and Curtis A (2013) 'Policy under pressure: policy analysis of community-based forest management in Indonesia', *International Forestry Review*, 15(3):398–405.

Wibowo LR, Wahyudiyati KT, Hayati N, Bisjoe ARH, Kurniasari DR and Herawati T (2019) Policy options for enhancing community-based commercial forestry In Indonesia, Project research report, Forestry and Environmental Research, Development and Innovation Agency (FOERDIA), Ministry of Environment and Forestry, Bogor, Indonesia.

Chapter 8

Matching farms and forests to a changing demographic in the Middle Hills of Nepal

Bhawana KC, Digby Race, Robert Fisher and William Jackson

Abstract

The context of farming and forestry in the rural landscapes of the Middle Hills region of Nepal is changing. Following outmigration, especially by men and young poeple from rural villages, women and the elderly have become responsible for managing farms and forests while continuing to fulfil their family responsibilities and undertake other community work.

Our research found that rural households in the region are moving towards low-input, less-intensive farming practices with fewer livestock and fewer crop rotations. This has led to underused and abandoned farmland that is increasingly covered in forests.

As a result, rural households are collecting forest products – such as firewood, timber and fodder/grass – from private forests and trees on farmland. The increasing number of trees on private farmland provides opportunities to generate multiple benefits for rural communities, including diversifying their livelihoods and improving economic development in the countryside.

Introduction

Rural outmigration is a widespread global phenomenon in low-income and medium-income countries (Ospina et al. 2019). As a result, rural areas are experiencing profound changes in the income and structure of rural households (Rigg et al. 2016; Shirai et al. 2017; Shirai and Rambo 2017). Both internal and international labour migration are driving livelihood diversification in developing countries (Wouterse and Taylor 2008). Several studies throughout the world have identified rural outmigration as one of the leading agents of socioeconomic change, of change in the management and use of natural resources, and of the transition in land use from local to regional levels (Chen et al. 2014; Ervin et al. 2019; KC et al. 2017; Lambin et al. 2001; Oldekop et al. 2018; Rudel et al. 2002; Walters 2016).

Over recent decades, outmigration has become a key livelihood strategy affecting an increasing number of rural households across Nepal. According to Nepal's population census in 2011, one in every 4 households (1.38 million households) had at least one family member absent for an extended period (domestically or abroad), and 85% of migrants were from rural families. A 2020 report indicates that the number of labour approvals issued by the Department of Foreign Employment increased to 106,660 in 2003–2004 from 3,605 in 1993–1994 and reached 519,638 in 2013–2014. Since 2013–2014, however, the volume of annual outmigration has decreased, and it plunged to 236,208 in 2018–2019 following the start of the COVID-19 pandemic (MoLESS 2020). In contrast, the value of remittances significantly increased from US$2.54 billion in 2010–2011 to US$8.79 billion in 2018–2019 (MoLESS 2020).

The highest proportion (45%) of the absent population is from the age group 15 to 24 years, according to Nepal's Central Bureau of Statistics (2012), and in 2018–2019 almost all (91%) migrant workers were male (MoLESS 2020). The highly gendered impact of outmigration has led to the 'feminisation' of rural communities, with women predominantly left to fill the gap created by the absence of men (Gulati 1987; Jaquet et al. 2015; KC and Race 2020b; Lastarria-Cornhiel 2006; Tiwari and Joshi 2015). Women and the elderly are often solely responsible for caring for family, farming, forest management and other community activities (Adhikari and Hobley 2015; Gartaula et al. 2010; KC and Race 2020b; Lahiri-Dutt and Adhikari 2016; Maharjan et al. 2012, 2013; Slavchevska et al. 2016; Tamang et al. 2014).

Demographic shifts have been identified as a threat to the long-term viability of local institutions (Hecht et al. 2015; Ostrom 2000; Shrestha and Fisher 2018; Wang et al. 2016). In Nepal, one of these institutions is the extensive network of local community forest user groups (CFUGs), which have been the primary mechanism for managing community forests since the 1990s. Under Nepal's community forestry program, local communities have conserved, managed and utilised forests for themselves. The Forest Act provides for a community forest constitution, which describes the rules and regulations that the CFUG must follow, including the conditions for collective action. CFUGs are expected to prepare an operational plan that outlines how the forest will be managed, including the allowable harvest. The CFUG's highest authority in the decision-making process is the general assembly, constituted from the households of all forest users who form the membership of the CFUG. A general assembly usually involves large open meetings of all members, held once or twice a year. The general assembly selects an executive committee with 10 to 15 members by consensus or election, which is responsible for governing the day-to-day management of community forests. The committee usually organises meetings once per month, or more frequently if required. The committee has the right and responsibility to enforce the decisions made by the general assembly (Banjade et al. 2006).

The changes created by outmigration – directly and indirectly – can have serious implications for local institutions, such as Nepal's CFUGs, given these institutions are designed in governance and practice around the active participation of a large proportion of the local community (Lambin et al. 2001). Basnett (2013) notes that questions of how migration is affecting the governance of forests and resource use remain unacknowledged and unaddressed following her review of forestry policies and research in Nepal.

Much empirical research has shown that the outmigration from rural areas of Nepal has a significant impact on agriculture. The shortage of labour, high labour costs and the additional work burden falling on women following the outmigration of men has led to abandonment and underutilisation of farmland, with increased forest cover as a consequence, and reduced dependency on natural resources (Jaquet et al. 2016; KC and Race 2020a; Khanal 2018; Qin 2010). Furthermore, lower financial returns from agriculture combined with increased income from remittances has led to a growing trend of rural households shifting towards non-farm livelihood options (Bhandari 2013; Jaquet et al. 2015, 2016, 2019; Marquardt et al. 2016; Ojha et al. 2017; Oldekop et al. 2018). Many rural households have improved their livelihoods with remittance income (Bhandari 2013; Fox 2016; Khanal et al. 2015), which has increased their capacity to buy food and invest in the health and education of their children (Gartaula et al. 2016; Jaquet et al. 2016; Thapa and Acharya 2017). People's livelihoods are thus disconnecting from their historical localised, agriculture-based economy. However, it is important to note that this disconnection is not absolute, but relative to previous conditions and may not apply to all households.

Since outmigration typically involves both rural communities and their management of resources, it inevitably affects forest resources through changes in forest use and management (Hecht et al. 2015), through an impact on household income, and through household decisions about local activities (Zhunusova et al. 2022). Several studies show that the effects of outmigration and incoming remittances on land use and resource use is context dependent. They can either promote regeneration of forest areas, as in El Salvador (Hecht and Saatchi 2007), or increase pressure over land use, as in Guatemala (Taylor et al. 2006). A study in the Philippines suggested that remittance income positively influences the area of land planted with perennials and reduces households' reliance on fuelwood use (Zhunusova et al. 2022). While some have noted that rural communities can at times appear passive or uninterested in addressing natural resource management issues, others have found that when rural communities are not solely reliant on agriculture for their income (for example, due to income from remittances) they can be more flexible with enterprise options and the use of farmland (Hecht et al. 2015; Rigg et al. 2012).

The links between migration and forests, however, are poorly understood (Robson and Klooster 2019). Despite the extensive literature on community forestry in Nepal, little is known about how CFUGs are being impacted by the combination of declining rural communities (in capacity and size) and the increasing availability of money in the rural economy following outmigration.

The relationships between outmigration and rural land-use transitions with community forest are highly complex, multidirectional, location-specific and not uniformly experienced. Thus, it is critical to understand local context when designing interventions, so that they address the dynamic changes rural communities are currently facing. In this chapter, we explore the changing context of farming and forestry in the rural landscape of the Middle Hills region of Nepal within the contemporary context of 'feminisation' of rural communities following outmigration. This research discusses the context pre-COVID-19. Outmigration may have reversed or slowed since the pandemic, requiring further assessment.

Study area

Our research was conducted in the district of Lamjung, in the Middle Hills region of Nepal, covering an area of 1,692 km^2. Historically, over two-thirds of the district's population depended largely on semi-subsistence agriculture and forestry for their livelihoods, with 32% of the district's forest being managed by local communities as community forests (332 CFUGs representing 26,109 households) (District Forest Office 2015). The district is dominated by very steep terrain (81%) and is well known for having the highest proportion of Gurung ethnic people (32%) in the country, with a further 29% of Brahmin or Chhetri descent. The district has a long tradition of Gurung men joining the British and Indian armies (known as *lahures* or Gurkhas), providing significant amounts of remittance income.

Figure 8-1: **(a) Rural landscape in Lamjung district, in the Middle Hills region of Nepal, showing distribution of human settlements, (b) Ploughing using oxen, (c) Firewood collected from private farmland for cooking, (d) Earthen road, (e) Women weeding a maize crop, (f) Women carrying fodder for livestock.**

Credit: Bhawana KC

In recent decades, remittance income has been reported as a major source of income for rural communities, with the district having an absentee household rate of 38% (Central Bureau of Statistics 2012). Three case study sites within the district – Gausahar, Samibhanjyan and Hilletaksar – were selected to include a wide range of sociodemographic characteristics, ethnic diversity, cultural backgrounds, mixed land use and livelihood options.

Generally, the study area is comprised of 3 categories of farmland – *khet*, *bari* and *kharbari*:

- *Khet* is relatively productive irrigated farmland located near waterways and traditionally focused on irrigated paddy (rice) cultivation.
- *Bari* is rain-fed farmland that is less productive than *khet* and is used to produce grains such as maize and millet.
- *Kharbari* is the least productive farmland, traditionally growing *khar* grass that is used for roof thatching and livestock feed, and often including some scattered trees.

Data collection

We collected primary data for the study using a mixed method approach – household surveys, in-depth interviews, focus group discussions and field observations. All interviews were conducted in the national Nepali language and most interviews were recorded using a voice recorder.

Secondary data were accessed from the meeting minutes of the CFUGs and reports from government and non-government organisations, such as the Central Bureau of Statistics and the Ministry of Labour and Employment.

Household surveys

We conducted 119 semi-structured household interviews with a person nominated by the family. Households in the study area were scattered in different hamlets (small villages) with limited or no transportation facilities, and it sometimes took more than one and a half hours to walk from one household to another.

It was hard to find households that did not have any member absent at the time of the survey. As a result, 77% of surveyed households were classified as 'migrant' households. Our definition of a migrant household includes both domestic (that is, within Nepal) and international migration where one or more members are absent for more than 6 months for any reason (for example, domestic work, foreign employment or education). Sometimes the distinction between migrant and non-migrant households was blurred as some households had members who were about to depart in the coming few days, some had already applied for visas to work abroad, some were waiting for overseas work placements and some, who had been working abroad, were at home but were planning to travel again and could have left the village at any time. Many non-migrant households included pension holders, returned migrants, or both, indicating that those households had been involved in migration in the past. However, these households were counted as non-migrant households as no-one was absent at the time of the survey. Likewise, many households in the study area were involved in rotational migration. For instance, several men were preparing to go abroad again for employment after staying home for a few months or years, or were seeking foreign employment having retired from army service. The sociodemographic characteristics of surveyed households are presented in Table 8-1.

Table 8-1: **Socioeconomic characteristics of the surveyed households (n = 119)**

Gender of the respondent	Male	Female			
	39%	61%			
Age of respondent (years)	Below 25	26–35	36–45	46–55	60+
	3%	15%	19%	24%	39%
Caste/ethnicity of household†	Brahmin or Chhetri	Janajati	Dalit		
	39%	41%	20%		
Type of household	Migrant household	Non-migrant household			
	92	27			
Migrant households					
Composition of migrant household	Parents only	Women with/without children	Women with/ without children and with parents	Others (extended or joint family)	
	42%	21%	20%	17%	
Number of absentee members of migrant households	1	2	3	4	>4
	47%	13%	14%	8%	18%

†Brahmin and Chhetri are the higher caste groups, as per the Hindu caste system, and are also known as upper caste people. Janajati are the middle caste groups. Dalits are the lower caste groups, commonly referred to as 'untouchables'.

In-depth interviews

We conducted 87 in-depth semi-structured interviews with individuals. The interviewees were purposively selected based on their availability, interest in being interviewed, age, gender, migration status, wellbeing status, village of residence, and past and/or current involvement with community forests, while ensuring even distribution across the hamlets. The households surveyed were largely excluded as interviewees, except for a few cases where individuals held or used to hold an important position associated with a CFUG or had relevant experience with the broader study topic.

Figure 8-2: **Conducting an in-depth interview**

Focus group discussions

We conducted 10 focus group discussions across the study area with current and former CFUG executive committee members (5), women's groups (3), and mixed groups (2), containing both migrant and non-migrant households with diverse socioeconomic status (in terms of gender, caste/ethnicity and wellbeing ranking). Topics covered included the changing socioeconomic dynamics of rural communities, changes in the use of forests and their management, changes in farming practices, changing responsibilities and decision-making roles, changes in the rural economy, and changes in land use and land cover.

Figure 8-3: Conducting a focus group discussion

Observations

The first author stayed in the study area for several months during the data collection process (conducted as part of her PhD study) and during this time observed rural households performing day-to-day activities related to decision making, livelihoods, collective action, land management and land-use transition. These included land-use practices, livestock rearing, intra-household and inter-household activities, market dynamics, collection of forest products, forest management, community meetings and construction activities.

Data analysis – land-use practice

Based on the household survey, we developed several broad categories of current land-use practice (Table 8-2). The ‘partly abandoned’ and ‘partly fallow’ categories were grouped into one broad category (that is, ‘underutilised farmland’), since these farmlands were not cultivated to full capacity.

Table 8-2: Status of land use by households interviewed

Category of land-use practice		Description
Abandoned		The household has retained their farm plots as uncultivated land for at least the last 2 years.
Underutilised farmland	Partly abandoned	The household has retained at least one of their farm plots as uncultivated land for at least 2 years.
	Partly fallow	The household has retained at least one of their farm plots as uncultivated land for 3 or more months in a year, resulting in a reduced number of crop rotations.
	Partly abandoned and partly fallow	The household has retained at least one of their farm plots as uncultivated land for more than 2 consecutive years and at least one of their farm plots as uncultivated land for 3 months in a year.
Continued farming		The household is continuing farming without any major changes in their land-use practice or scale of farmland.
Farmed by others		The household has given their farmland to others to farm for a specific period of time (*adiya*[†] or *bandage/ujinta*[‡]).

† Sharecropping, usually with an informal contract where the landowner and tenants share equally in the resulting agricultural production

‡ Farmland is leased or rented to tenants for a specified period at a fixed price, paid in cash. Unlike the sharecropping arrangement, the tenants do not share any production with the landowner.

Results: Who are today’s farmers?

Most households surveyed consisted of a female with children and/or elderly people, who are largely responsible for farming and other community work, such as community forest management and attending various meetings. Elderly people generally do domestic chores, take care of grandchildren and support farming if they are living in a joint family or with their daughters-in-law. Elderly people were continuing to farm as much as they physically could to support the household, or they had given their farmland to others for farming if they were living alone. Most men were working abroad, in the Nepali, Indian or British armies, or in jobs in various cities. Most younger children had moved to the district headquarters, to cities or to the capital, Kathmandu, to pursue education. There is an increasing trend for remaining family members to seek remittances and/or earn money from other livelihood sources, then move to road junctions or the district headquarters, a nearby town or city, or Kathmandu to access better education and better facilities. It is generally believed that urban centres have better quality education than government schools and children can learn English in private schools. Most government schools in the study area were close to shutting down, with as few as 3 to 10 students enrolled in total, and some had already closed. Quite a few young people had left their village as they were not interested in continuing farming or were not involved in farming because most parents wanted their children to focus on study and get away from the physically hard and unprofitable agricultural work.

Compared to people working abroad, men working in the Nepali army or employed in nearby cities tended to visit home as much as possible, particularly during the peak agricultural seasons to support farming. Likewise, we found that it was common for daughters-in-law who had moved to nearby towns or cities to visit home to support farming. It was widely mentioned that the study area is facing acute labour shortages leading to expensive labour costs and difficulty in finding male agricultural labourers and oxen for ploughing in a timely manner. It is especially challenging for women and elderly heads of households that do not have any young adults at home to participate in the traditional arrangement of labour exchange or find money to pay labourers.

According to a lower caste woman from a migrant household:

> For households headed by women, it is relatively easy to do farming if the women have money compared to those who don't, as labourers prefer to go first where they can get cash. Otherwise, they have to do late farming [risking missing out on crucial rainfall]. However, male labourers give priority to those households headed by men, even though the women have cash. It is very difficult for women-headed households to do farming if they don't have any male labour for exchange and are financially poor.

It was widely recognised that numbers of oxen, cattle and buffalo have fallen dramatically as they require more care and food compared to goats. In the study area, oxen are used for ploughing and, according to gender norms, ploughing is a task exclusively done by men. In the absence of men in the household, women must employ men to plough their fields. This has discouraged female and elderly households from keeping oxen. Instead, households were attracted to raising goats as they are a quick source of money (for more details, see KC and Race 2020b).

A few households in the study area have started commercial farming – for example, raising poultry or goats, growing vegetables, some with tunnel farming[14] – or grocery businesses, supplemented by remittances, pensions or other income sources. For instance, after retiring from the army one farmer decided to start farming goats at a commercial scale and raising small poultry, as this enabled better use of underutilised farmland and required less labour than traditional cropping.

Figure 8-4: **(Left) An example of an abandoned household in the study area. (Right) An example of abandoned farmland in the study area**

14 Tunnel farming is when a small plastic greenhouse-like structure is used to keep the soil warm and to promote germination.

Figure 8-5: **A fodder plantation on underutilised farmland**

Figure 8-6: **Goat farming can be a quick source of money.**

Figure 8-7: **A small grocery shop in a village**

Land-use practice

Most households have changed their farming practices and it is easy to find abandoned or underutilised farmland. Fewer households are continuing their traditional livelihoods with agriculture as their primary source of income (Figure 8-8). Underutilisation of farmland is becoming a common trend among rural households as is the abandonment of farmland. Our study found that even the productive *khet* farmland was being abandoned and underutilised. Farmers have also significantly reduced the number of crop rotations in recent years and they are often leaving their farmland fallow or uncultivated for a few months each year. For instance, in *khet* lands, farmers were usually undertaking paddy cultivation only once a year and otherwise leaving the *khet* fallow, with this uncultivated land being used as grazing land or occupied by invasive species.

A female from a migrant household living by herself with a child said:

> [...] I am doing only 2 crop rotations in *bari* which remains fallow for a few months between maize and millet. Likewise, I am only planting paddy once in a year in *khet* because I am unable to do work by myself. At the same time, *khet* is located far from the house and I have difficulty getting labourers and ox when required.

The abandonment and underutilisation of farmland is not only prevalent among migrant households, which indicates that other factors affect the decisions of farmers to continue, underutilise or abandon farming. This finding aligns with many researchers, who have mentioned migration is not the sole reason behind abandonment or underutilisation of farmland (KC and Race 2020a).

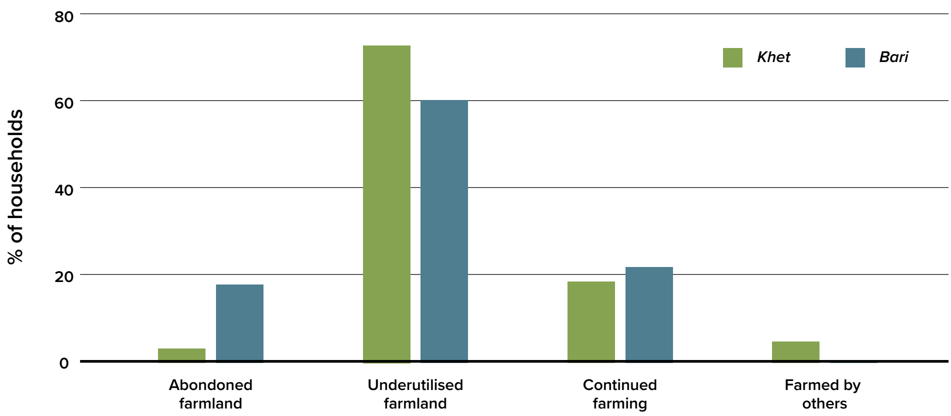

Figure 8-8: **How surveyed households are using their land. *Khet* is relatively productive irrigated farmland. *Bari* is less productive rain-fed farmland.**

All research participants reported that forest cover has increased significantly in the rural landscape, including through natural regeneration on private farmland or through planting of fodder and timber species, as well as grass (Figure 8-9 and Figure 8-10).

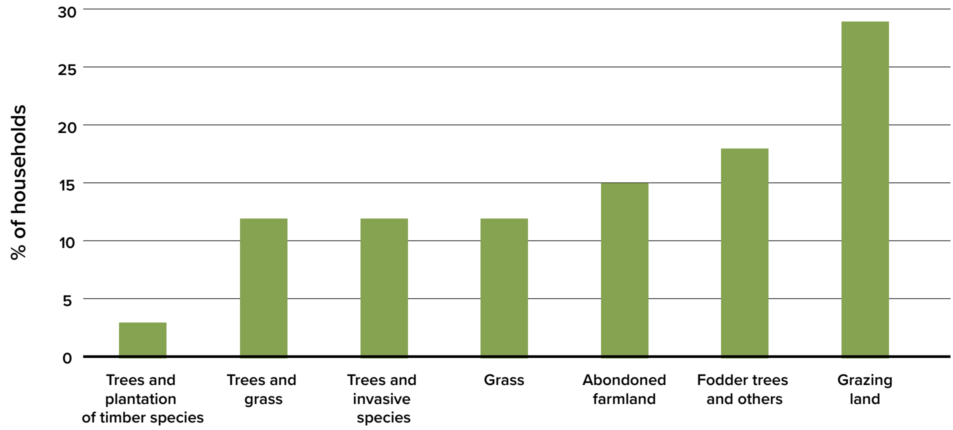

Figure 8-9: Land cover of abandoned *khet*

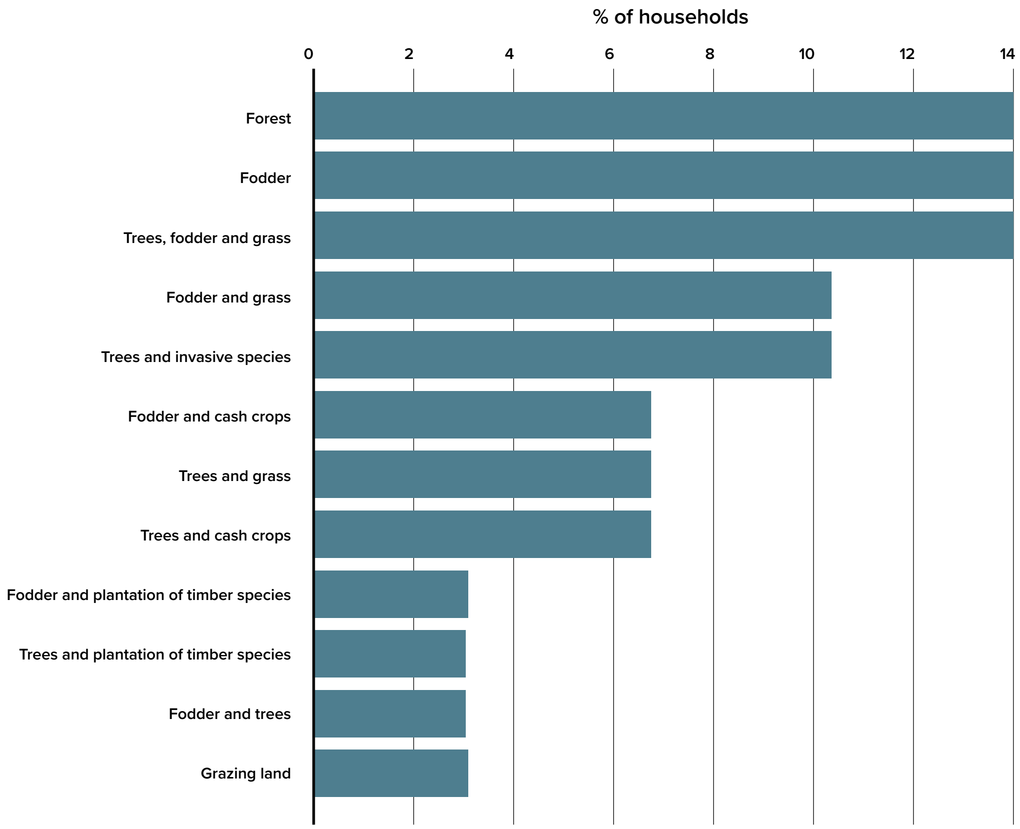

Figure 8-10: Land cover of abandoned *bari*

All households surveyed reported that most *kharbari* had been converted to forest through natural regeneration of native trees. Abandoned *khet* and *bari* have increasing numbers of trees through natural regeneration and, in some cases, through planting of fodder and other trees species. Preferred fodder species include rai kanayo (*Ficus semicordata*), gindari (*Premma Latifolia*), kutmero (*Litsea polyantha*), kabro (*Ficus lacor*), dabdabe (*Garuga Pinnata*), tanki (*Bauhinia purpuria*), badahar (*Artocarpus lakoocha*), nimaro (*Ficus roxburghii*), koiralo (*Bauhinia variegate*), khasreto (*Ficus hispida*) and pakhuri (*Ficus glaberima*).

Farmers indicated they were increasingly interested in planting timber species for future income – such as teak (*Tectona grandis*), sal (*Shorea robusta*) and sissoo (*Dalbergia sissoo*) – on their abandoned farmland, which is usually located far away from human settlements.

Figure 8-11: *Kharbari* converted to naturally regenerating forest
Credit: Bhawana KC

In one case, an entire family had moved to the district headquarters for business and had planted teak on 3 *ropani*[15] of farmland (Figure 8-12).

Figure 8-12: A new teak plantation on fallow farmland
Credit: Bhawana KC

15 The *ropani* is a unit of land measurement used in the hills. One *ropani* is equivalent to 0.015 ha.

Figure 8-13: **Trees regenerating on abandoned terraced farmland**

Credit: Bhawana KC

Figure 8-14: **(a) Cash crop plantation, (b) Abandoned farmland covered in naturally regenerating and planted grass for livestock, (c) Planted grass species in abandoned cropland, (d) Abandoned farmland with trees regenerating naturally**

Credit: Bhawana KC

Our research participants reported that farmers preferred to collect firewood, fodder, grass and timber from private farmland or private forest, as it is more convenient and gives them more flexibility than collecting it from community forests where households must harvest it within approved periods and at specific locations. For example, participants in focus group discussions reported that only 2 out of 26 households in Gausahar collected firewood from community forests – the remaining households collected firewood from private farmland because it was closer, making it both easier to transport and cheaper. Consumption of firewood has dropped significantly with improved access to alternative sources of energy (such as electricity and liquified petroleum gas (LPG)), fewer resident family members, fewer livestock and rising labour and transportation costs. In the district overall, the dependency on forest products harvested from community forests has reduced, leading to changes in the management of community forests (KC et al. 2021).

Figure 8-15: (a) A farmer collects firewood from his private farmland, (b) Firewood collected from abandoned *bar*i, (c) Households are becoming less dependent on firewood for cooking.

Credit: Bhawana KC

Case study: Household living as a joint family

Foreign employment and a regular job are major sources of income for this household. The elder son (in the 25–34 age bracket) has been in foreign employment for the last 12 years in various Gulf countries, including Saudi Arabia, United Arab Emirates and Qatar. Another son has been in Kathmandu for the last 11 years working in a paid job, having finished his studies. The parents are living with 2 daughters-in-law and grandchildren. Out of their 12-*ropani* farmland, 3.5 *ropani* of *khet* and 2 *ropani* of *bari* have been left abandoned for the last 7 years due to lack of human resources at home and the unprofitable nature of farming. Instead of practising traditional cropping, fodder and timber trees (sal and sissoo) have been planted on their farmland. One *ropani* of *kharbari* has been converted to forest by naturally regenerated trees, with a few *khar* grasses. The *khet* that was previously managed under sharecropping has been abandoned as it is difficult to find people who are interested in sharecropping. People prefer to work in the market, which is easier and more profitable, and an individual can earn more money quicker than working as agricultural labour. One *ropani* of *khet* that had been abandoned 8 years is now a private forest.

Household farming is now limited to nearby farmlands due to a lack of human resources at home, the older people being unable to continue farming and the 2 daughters-in-law busy taking care of children. Farmland that is further away has been abandoned and the number of livestock has fallen from 20 goats, 2 oxen and 3 buffalo to only 2 buffalo and 7 goats. The household has diversified income sources, with 25% of their household income coming from vegetable farming and from the local sale of small items of home-made furniture.

The household head stated that they will continue farming as long as they can, but their children will not continue farming as they wanted an easier lifestyle. With more trees on their private land, the household has been collecting forest products from their own forest and farmland for the last 20 years, rather than from the community forest – even though they are entitled to do so. The only forest product they had collected from community forests was 10–12 cubic feet (0.34 m^3) of timber 5 years previously for house construction.

Figure 8-16: (Left) Abandoned terraced farmland naturally regenerating with trees and grass, with some planted trees. (Right) A local forest-based enterprise

Case study: A household managed by elderly parents

Out of 8 family members, including grandchildren, only the elderly parents live at home. Both sons are working abroad. Both daughters-in-law have moved to Kathmandu – the younger one moved one year ago for study and the elder daughter and her children moved 5 years ago for education. The parents moved to the roadhead 6 years ago and started a grocery business. Foreign employment is the highest source of their household income, with their sons contributing 60% of total income and the family's grocery business contributing a further 20%. The family is interested in expanding their grocery business instead of continuing farming. The daughters-in-law do not want to continue farming and the son will not work on the farm after he returns from abroad. The sons want to build a house in Kathmandu using remittances, as a house is a sign of prestige in the village, and to invest in the children's education.

Out of 14 *ropani* of *khet*, 4 *ropani* has been abandoned for 7 years and it is now converted to *kharbari* containing naturally regenerated trees, with some planted fodder and timber trees. The elderly parents are unable to continue farming due to declining physical strength and because farming has become unprofitable. Six *ropani* of *khet* is under sharecropping, where the paddy that is harvested is divided equally between the sharecropper and landowner. The household has sold fodder and grass from 6 *ropani* of *kharbari* for the past 6 years, which has been made possible due to the household keeping fewer livestock. These days, they keep only 6 goats and one calf, compared to the 2 oxen, 2 buffalo and 15–20 goats that they kept in the past. The reasons given for the reduced number of livestock included fewer human resources being at home and that buffalo took considerable time to manage. It was reported that goats are easy to manage and provide a quick source of income compared to other livestock.

Sharecroppers are reportedly very hard to get these days – increasing access to markets enables a labourer to work 2 days for one sack of rice, instead of doing the hard work required for agriculture. Moreover, farming is increasingly seen as unprofitable. Most households were not collecting any forest products from community forests. The primary sources of energy used by the household for cooking were LPG and electricity, with firewood use being limited to cooking porridge for livestock and for boiling milk. This situation contrasts markedly from the past when firewood was the major source of energy in the rural landscape.

Case study: A migrant household

[...] it's cheaper to buy agricultural products from market instead of doing farming [...]

The elderly parents are living by themselves as their daughter has married and now lives elsewhere. Their elder son (aged 28 years) is working as a journalist and has been away from home for the past 7.5 years, while their younger son (aged 18 years) is taking excavator training. The parent interviewed is working as a teacher in the village public school.

Out of 12 *ropani* of *khet* and 10 *ropani* of *bari*, the household is continuing to farm only 2.5 *ropani* and 3.5 *ropani*, respectively. Five *ropani* of *khet* was under sharecropping for 5 years, but since last year it has remained fallow as the husband of the sharecropping family took up foreign employment and the household found it difficult to continue farming. The family is facing a hard time to secure another sharecropper. Eight *ropani* of *bari* is fallow due to increased crop damage by monkeys; wildlife numbers are increasing in the rural landscape and fewer people are at home to protect crops. Three *ropani* of *kharbari* have been converted to forest and the household has planted a cash crop of turmeric in their abandoned *khet*. Turmeric is attacked less by wildlife and is easy to maintain. Planted timber and fodder trees are found on the remaining farmland.

The farmer is cultivating paddy only once a year and otherwise leaves the farmland fallow because there are fewer people at home, the surrounding farmlands are fallow, and the remaining crops are highly susceptible to crop damage by monkeys. The family wants to focus on raising goats in the future to provide a quick source of income, rather than continuing farming; this is due to the lack of people at home, the high level of investment required for a low benefit, expensive labour and low prices in the market. The farmer mentioned that their son wants to focus on other jobs and that farming has become their last option for income because agriculture is unprofitable and hard work. He added that they have been unable to undertake farm work at the right time as it was hard to get agricultural labour in a timely manner.

Case study: An ageing non-migrant household

This household has 4 family members, 3 of whom are over 55 years of age and one 30-year-old son. The parents will continue farming until they are no longer able to farm. The parents mentioned that their son is not interested in continuing farming and that he is planning to work abroad.

As their *khet* is located far away from human settlement, the family is doing only one crop rotation in *khet* due to crop damage by monkeys and the difficulty and cost of securing labour. Instead, they have planted cash crops such as cardamom in 7 *haal*[16] of farmland. It was reported that 2 *haal* of *khet* were given to others as *adiya* (sharecropping) but since last year they had discontinued farming as they were getting older and unable to continue farming. One *haal* of productive *khet* has been left abandoned for the past 2 years, as it is located far away from the house. The household is collecting forest products from private forest and farmland, rather than from community forest.

Case study: A non-migrant household surviving on outside sources of income

> **[...] people used to carry sick people on a stretcher when there were no road facilities at the village, but now there are no young people in the village to carry sick people even to a vehicle [...]**

Our interviewee stated that most households in the study area are abandoning more distant farmland or growing only one crop rotation of paddy each year on far away farmland and limiting most farming to near human settlements – this is due to increasing crop damage by wildlife, difficulty in securing agricultural labour and increasingly erratic rainfall patterns. Farming is considered unprofitable and increasingly uncertain.

The major income sources of this household are pensions from the Nepali army and carpentry work. Two *haal* of *bari* have been left abandoned for 7 years, as the land is far away from human settlement and facing increasing crop damage by wildlife. Their *kharbari* has already been converted to forest. The household is planning to do even more carpentry work and continue farming for self-consumption because of increasing uncertainty in farming following erratic rainfall patterns, wildlife damage, decreasing productivity and unprofitability. The farmer emphasised that her son will not continue farming or it will be a last option if he cannot get a job anywhere.

The household's main source of energy for cooking is electricity and LPG. Firewood is used for boiling milk and cooking porridge for livestock. Instead of collecting fuelwood and fodder from the community forest, the household collects products from private land and from their *kharbari*, which have been converted to forest.

16 The *haal* is a unit of land measurement in Nepal, mainly used by rural people. One *haal* is the area that a pair of bullocks (and human labour) can plough in a day.

Conclusions

Demographic and related socioeconomic changes in the rural economy, including an increasing reliance of rural households on remittances, have become major agents affecting land use in the Middle Hills region of Nepal. Abandonment of farmland and an increasing trend of leaving farmland fallow or uncultivated for a few months each year is reducing the intensity and scale of farming, leading to households underutilising farmland – an observation made by several other studies in Nepal (Khanal 2018; Ojha et al. 2017). Rural communities are moving towards less-intensive, small-scale farming and most households are focusing, or planning to focus, their farming on meeting their household consumption needs only.

Abandoned and underutilised farmland is increasingly being covered in forest, as other studies in Nepal also found (Jaquet et al. 2016; KC et al. 2017; KC and Race 2020a; Khanal and Watanabe 2006; Oldekop et al. 2018). With more trees on private farmland, many rural households are collecting forest products (firewood, timber, fodder and grass) from private forests and trees on farmland instead of from community forests. This has decreased the dependency of rural households on community forests for forest products. However, it is important to note the impacts on households without land or with very little land may be different compared to those households with sufficient land for private forests and trees, or sufficient remittances – a situation that requires further investigation. The increasing number of trees on farms provides an opportunity to generate multiple benefits for rural communities, including to diversify rural livelihoods and increase socio-ecological resilience to climate change. Some studies in Nepal have shown that trees on private farmland offer multiple benefits, such as diversifying rural livelihoods, improving food security and addressing the negative impacts of climate change (Bajracharya et al. 2015; Pandit et al. 2014, 2018; Pokharel et al. 2022).

For example, our study suggests that most *kharbari* and other abandoned and underutilised farmland have become sites for naturally regenerated trees, which can potentially be used for timber production. However, in most of these cases, the farmlands have not been registered to private forest. Several farmers mentioned they were concerned that if they converted private farmland to forest, the land would be taken by the government.

A recent study about the private forest program in Nepal suggests that the government initiatives are inadequate to facilitate private forest development. In the past, policy provisions were poorly implemented, with lengthy and complex institutional arrangements and procedures for harvesting and selling timber from both registered and unregistered private forest (Aryal et al. 2020).

To optimise the value from abandoned or underutilised farmland that is regenerating to forest (for example, for timber production), the government needs to improve polices related to private forest and trees, improve access to incentives (for example, insurance and land tax remissions), and enhance technical knowledge and awareness raising among the rural population.

Households' declining reliance on community forest for forest products is creating opportunities to refocus community forest management away from a primary emphasis on meeting semi-subsistence needs to include a focus on developing enterprise, conserving biodiversity and generating flows of a broader range of ecosystem services. Examples are carbon sequestration and the introduction of payments for ecosystem services.

To promote environmental sustainability and economic development of Nepal, the government should introduce policy measures that support farmers to produce timber on abandoned or underutilised private farmland. These measures should be supported by facilitating the private forest registration process, providing seedlings of timber species, and building capacity and awareness among farmers to improve the quality and scale of private forestry for timber and other ecosystem services.

To fully reap the benefit of naturally regenerating forests on private farmland for timber production, simple silvicultural techniques and guidelines should be promoted which can be easily followed without extensive support from forestry technicians. Likewise, to encourage local enterprise the government should remove regulatory impediments to rural communities seeking to add value to timber and marketing their forest products.

These land-use options for Nepal are consistent with suggestions arising from other international cases, including the suggestions to increase forest area in private farmland (for example, via agroforestry). Agroforestry would provide an appealing option for sequestering carbon on agricultural lands and for addressing climate change adaptation and mitigation, while enabling continued farming, more secure rural communities and improved food security (Fouladbash and Currie 2015; Kumar and Nair 2011; Schoeneberger 2009).

References

Adhikari J and Hobley M (2015) '"Everyone is leaving who will sow our fields?": The livelihood effects on women of male migration from Khotang and Udaypur districts, Nepal, to the gulf countries and Malaysia', *Himalaya*, 35(1):11–23.

Aryal K, Rijal A, Maraseni T and Parajuli M (2020) 'Why is the private forest program stunted in Nepal?', *Environmental Management*, 66(4):535–548, doi:10.1007/s00267-020-01343-z.

Bajracharya RM, Shrestha HL, Shakya R and Sitaula BK (2015) 'Agro-forestry systems as a means to achieve carbon co-benefits in Nepal', *Journal of Forest and Livelihood*, 13(1),58–70, doi:10.3126/jfl.v13i1.15366.

Banjade MR, Schanz H and Leeuwis C (2006) 'Discourses of information in community forest user groups in Nepal', *International Forestry Review*, 8(2):229–240, doi:10.1505/ifor.8.2.229.

Basnett BS (2013) 'Taking migration seriously: what are the implications for gender and community forestry?', *CIFOR Infobrief*, No. 65, July 2013, Center for International Forestry Research, Bogor, Indonesia.

Bhandari PB (2013) 'Rural livelihood change? household capital, community resources and livelihood transition', *Journal of Rural Studies*, 32:126–136, doi:10.1016/j.jrurstud.2013.05.001.

Central Bureau of Statistics (2012) *National population and housing census 2011 (National report)* (Vol. 01), National Planning Commission Secretariat, Government of Nepal.

Chen R, Ye C, Cai Y, Xing X and Chen Q (2014) 'The impact of rural out-migration on land use transition in China: past, present and trend', *Land Use Policy*, 40:101–110, doi:10.1016/j.landusepol.2013.10.003.

District Forest Office (2015) *Community forest user groups monitoring and evaluation*, Lamjung District Forest Office, Lamjung, Nepal.

Ervin D, López-Carr D, Riosmena F and Ryan SJ (2019) 'Examining the relationship between migration and forest cover change in Mexico from 2001 to 2010', *Land Use Policy*, 91:104334, doi:10.1016/j.landusepol.2019.104334.

Fouladbash L and Currie WS (2015) 'Agroforestry in Liberia: household practices, perceptions and livelihood benefits', *Agroforestry Systems*, 89(2):247–266, doi:10.1007/s10457-014-9763-9.

Fox J (2016) 'Community forestry, labor migration and agrarian change in a Nepali village: 1980 to 2010', *The Journal of Peasant Studies*, 6150(December):1–20, doi:10.1080/03066150.2016.1246436.

Gartaula HN, Niehof A and Visser L (2010) 'Feminisation of agriculture as an effect of male out-migration: unexpected outcomes from Jhapa district, Eastern Nepal', *The International Journal of Interdisciplinary Social Sciences*, 5(2):565–577.

Gartaula HN, Patel K, Johnson D, Devkota R, Khadka K and Chaudhary P (2016) 'From food security to food wellbeing: examining food security through the lens of food wellbeing in Nepal's rapidly changing agrarian landscape', *Agriculture and Human Values*, 34(573–589), doi:10.1007/s10460-016-9740-1.

Gulati L (1987) 'Coping with male migration', *Economic & Political Weekly*, 22(44):WS41–WS46.

Hecht SB and Saatchi SS (2007) 'Globalization and forest resurgence: changes in forest cover in El Salvador', *BioScience*, 57(8):663–672, doi:10.1641/b570806.

Hecht SB, Yang AL, Basnett BS, Padoch C and Peluso NL (2015) 'People in motion, forests in transition: trends in migration, urbanization, and remittances and their effects on tropical forests', *CIFOR Occasional Paper*, Issue 142, Center for International Forestry Research, Bogor, Indonesia, doi:10.17528/cifor/005762.

Jaquet S, Kohler T and Schwilch G (2019) 'Labour migration in the middle hills of Nepal: Consequences on land management strategies', *Sustainability*, 11(5):1349, doi:10.3390/su11051349.

Jaquet S, Schwilch G, Hartung-Hofmann F, Adhikari A, Sudmeier-Rieux K, Shrestha G, Liniger HP and Kohler T (2015) 'Does outmigration lead to land degradation? labour shortage and land management in a western Nepal watershed', *Applied Geography*, 62:57–170, doi:10.1016/j.apgeog.2015.04.013.

Jaquet S, Shrestha G, Kohler T and Schwilch G (2016) 'The effects of migration on livelihoods, land management, and vulnerability to natural disasters in the Harpan watershed in western Nepal', *Mountain Research and Development*, 36(4):494–505, doi:10.1659/MRD-JOURNAL-D-16-00034.1.

KC B and Race D (2020a) 'Outmigration and land-use change: a case study from the middle hills of Nepal', *Land*, 9(2):1–19.

——(2020b) 'Women's approach to farming in the context of feminization of agriculture: a case study from the middle hills of Nepal', *World Development Perspectives*, 20(June):100260, doi:10.1016/j.wdp.2020.100260.

KC B, Race D, Jackson W and Fisher B (2021) 'Changing rural livelihoods and forest use transition in the middle hills of Nepal', *Small-scale Forestry*, doi:10.1007/s11842-021-09477-6.

KC B, Wang T and Gentle P (2017) 'Internal migration and land use and land cover changes in the Middle Mountains of Nepal', *Mountain Research and Development*, 37(4):446–455, doi:10.1659/MRD-JOURNAL-D-17-00027.1.

Khanal NR and Watanabe T (2006) 'Abandonment of agricultural land and its consequences', *Mountain Research and Development*, 26(1):32–40.

Khanal U (2018) 'Why are farmers keeping cultivatable lands fallow even though there is food scarcity in Nepal?', *Food Security*, 10:603–614, doi:10.1007/s12571-018-0805-4.

Khanal U, Alam K, Khanal RC and Regmi PP (2015) 'Implications of out-migration in rural agriculture: a case study of Manapang village, Tanahun Nepal', *The Journal of Developing Areas*, 49(1):331–352, doi:10.1353/jda.2015.0012.

Kumar BM and Nair PKR (eds) (2011) *Carbon sequestration potential of agroforestry systems: opportunities and challenges*, Advances in Agroforestry series (Vol. 8), Springer, Dordrecht.

Lahiri-Dutt K and Adhikari M (2016) 'From sharecropping to crop-rent: women farmers changing agricultural production relations in rural South Asia', *Agriculture and Human Values*, 33:997–1010, doi:10.1007/s10460-015-9666-z.

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C, George PS, Homewood K, Imbernon J, Leemans R, Li X, Moran EF, Mortimore M, Ramakrishnan PS, Richards JF, Skanes H, Steffen W, Stone GD, Svedin U, Veldkamp TA, Vogel C and Xu J (2001) 'The causes of land-use and land-cover change: moving beyond the myths', *Global Environmental Change*, 11(4):261–269, doi:10.1016/S0959-3780(01)00007-3.

Lastarria-Cornhiel S (2006) *Feminization of agriculture: trends and driving forces*, Background paper for the World Development Report 2008, Latin American Center for Rural Development, Santiago, Chile.

Maharjan A, Bauer S and Knerr B (2012) 'Do rural women who stay behind benefit from male out-migration? a case study in the hills of Nepal', *Gender, Technology and Development*, 16(1):95–123, doi:10.1177/097185241101600105.

——(2013) 'International migration, remittances and subsistence farming: evidence from Nepal', *International Migration*, 51(S1), doi:10.1111/j.1468-2435.2012.00767.x.

Marquardt K, Khatri D and Pain A (2016) 'REDD+, forest transition, agrarian change and ecosystem services in the hills of Nepal', *Human Ecology*, 44(2):229–244, doi:10.1007/s10745-016-9817-x.

MoLESS (Ministry of Labour, Employment and Social Security) (2020) *Nepal labour migration report 2020*, MOLESS, Government of Nepal.

Ojha HR, Shrestha KK, Subedi YR, Shah R, Nuberg I, Heyojoo B, Cedamon E, Rigg J, Tamang S, Paudel KP, Malla Y and McManus P (2017) 'Agricultural land underutilisation in the hills of Nepal: investigating socio-environmental pathways of change', *Journal of Rural Studies*, 53:156–172, doi:10.1016/j.jrurstud.2017.05.012.

Oldekop JA, Sims KRE, Whittingham MJ and Agrawal A (2018) 'An upside to globalization: international outmigration drives reforestation in Nepal', *Global Environmental Change*, 52:66–74, doi:10.1016/j.gloenvcha.2018.06.004.

Ospina D, Peterson G and Crépin AS (2019) 'Migrant remittances can reduce the potential of local forest transitions: a social-ecological regime shift analysis', *Environmental Research Letters*, 14(2), doi:10.1088/1748-9326/aaf0ee.

Ostrom E (2000)' Collective action and the evolution of social norms', *The Journal of Economic Perspective*, 14(3):137–158.

Pandit BH, Nuberg I, Shrestha KK, Cedamon E, Amatya SM, Dhakal B and Neupane RP (2018) 'Impacts of market-oriented agroforestry on farm income and food security: insights from Kavre and Lamjung districts of Nepal', *Agroforestry Systems*, 2016(GoN 2016), doi:10.1007/s10457-018-0273-z.

Pandit BH, Shrestha KK and Bhattarai SS (2014) 'Sustainable local livelihoods through enhancing agroforestry systems in Nepal', *Journal for Forest and Livelihoods*, 12(1):47–63.

Pokharel S, Bhattarai S, Adhikari R, Jha S, Pokhrel A and Parajuli M (2022) 'Existing agroforestry practices and their contribution to the socio-economic condition of the people of west Nawalparasi, Nepal: a case study', *Archives of Agriculture and Environmental Science*, 7(1):132–141, doi:10.26832/24566632.2022.0701019.

Qin H (2010) 'Rural-to-urban labor migration, household livelihoods, and the rural environment in Chongqing municipality, southwest China', *Human Ecology*, 38(5):675–690, doi:10.1007/s10745-010-9353-z.

Rigg J, Salamanca A and Parnwell M (2012) 'Joining the dots of agrarian change in Asia: a 25 year view from Thailand', *World Development*, 40(7):1469–1481, doi:10.1016/j.worlddev.2012.03.001.

Rigg J, Salamanca A and Thompson EC (2016) 'The puzzle of East and Southeast Asia's persistent smallholder', *Journal of Rural Studies*, 43:118–133, doi:10.1016/j.jrurstud.2015.11.003.

Robson JP and Klooster DJ (2019) 'Migration and a new landscape of forest use and conservation', *Environmental Conservation*, 46:1–8.

Rudel TK, Bates D and Machinguiashi R (2002) 'A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon', *Annals of the Association of American Geographers*, 92(1):87–102, doi:10.1111/1467-8306.00281.

Schoeneberger MM (2009) 'Agroforestry: working trees for sequestering carbon on agricultural lands', *Agroforestry Systems*, 75(1):27–37, doi:10.1007/s10457-008-9123-8.

Shirai Y, Fox J, Leisz SJ, Fukui H and Rambo AT (2017) 'The influence of local non-farm employment on rural household structure in Northeast Thailand', *Journal of Rural Studies*, 54:52–59, doi:10.1016/j.jrurstud.2017.06.003.

Shirai Y and Rambo AT (2017) 'Household structure and sources of income in a rice-growing village in Northeast Thailand', *Southeast Asian Studies*, 6(2):275–292, doi:10.20495/seas.6.2_275.

Shrestha K and Fisher R (2018) 'Labour migration, the remittance economy and the changing context of community forestry in Nepal', in Thwaites R, Fisher R and Poudel M (eds) *Community forestry in Nepal: adapting to a changing world*, pp. 171–192, Routledge, UK.

Slavchevska V, Kaaria S and Taivalmaa S (2016) *World feminization of agriculture in the context of rural transformations : What is the evidence ?* [working paper], World Bank, Washington, DC.

Tamang S, Paudel KP and Shrestha KK (2014) 'Feminization of agriculture and its implications for food security in rural Nepal', *Journal of Forest and Livelihood*, 12(1):20–32.

Taylor MJ, Moran-Taylor MJ and Ruiz DR (2006) 'Land, ethnic, and gender change: transnational migration and its effects on Guatemalan lives and landscapes', *Geoforum*, 37:41–61, doi:10.1016/j.geoforum.2004.12.002.

Thapa S and Acharya S (2017) 'Remittances and household expenditure in Nepal : evidence from cross-section data', *Economies*, 5(16):1–17, doi:10.3390/economies5020016.

Tiwari PC and Joshi B (2015) 'Climate change and rural out-migration in Himalaya', *Change and Adaptation in Socio-Ecological Systems*, 2(1):8–25., doi10.1515/cass-2015-0002.

Walters BB (2016) 'Migration, land use and forest change in St. Lucia, West Indies', *Land Use Policy*, 51:290–300, doi:10.1016/j.landusepol.2015.11.025.

Wang Y, Chen C and Araral E (2016) 'The effects of migration on collective action in the commons: evidence from rural China', *World Development*, 88:79–93, doi:10.1016/j.worlddev.2016.07.014.

Wouterse F and Taylor JE (2008) 'Migration and income diversification: evidence from Burkina Faso', *World Development*, 36(4):625–640, doi:10.1016/j.worlddev.2007.03.009.

Zhunusova E, Lippe M, Yang AL and Günter S (2022) 'The implications of remittances for agricultural land use and fuelwood collection: evidence from the remaining forested landscapes in the Philippines', *Environmental Research Letters*, 17(2), doi:10.1088/1748-9326/ac44c4.

Chapter 9

Developing ‘farmer first’, locally adapted agroforestry in eastern Africa

Catherine Muthuri, Caroline Njoki, Ruth Kinuthia, Athanase Mukuralinda, Wondwossen Gebretsadik, Charles Galabuzi, Jean Damascene Ndayambaje, Clement Okia, Anne Kuria, Judith Oduol, Philip Smethurst, Abayneh Derero, Athanase Rusanganwa Cyamweshi, Shiferaw Tadesse, Joel Buyinza, Awol Toib, Maimbo Malesu, James Kung’u, Abrham Girmay, Sammy Carsan, Alex Mugayi, Immaculate Sekkito, Assefa Tofu, Kiros Hadgu, Jeremias Mowo and Fergus Sinclair

Abstract

Over 110 million people in Ethiopia, Rwanda and Uganda depend upon smallholder farming practised across 25 million ha of land. Smallholders generally focus on subsistence, use low levels of external inputs, depend on rainfall rather than irrigation and have limited market access. Most rural households are resource poor, food insecure and vulnerable to climate change, particularly frequent droughts and flooding and global warming. This situation is compounded by population growth (3% per year across the region) and an increased demand for food, water and energy, coupled with declining farm productivity, over-exploitation of trees in agricultural landscapes, and deforestation.

This was the context for our research which sought to improve food security and smallholder livelihoods through the widespread adoption of appropriate, locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda. Through research and development, we accelerated farmers' adoption of new technologies to better manage trees on farms and in farming landscapes, we promoted new marketing strategies to farmers, and we raised awareness of financial options that could enhance tree-based value chains.

We also focused on building capacity of key stakeholders in agroforestry. Through a participatory, bottom-up approach, farmers harnessed local and scientific knowledge to determine locally suitable agroforestry options. This was achieved through more than 5,000 participatory trials, and the efficient supply of high-quality germplasm – over 4.2 million germplasms were produced by 5 rural resource centres (RRCs) established under our project (Muthuri et al. 2021b). The trials and supply of germplasm led the RRCs to shift priorities from growing a narrow range of tree species to pursuing broader and higher quality agroforestry options to improve the food security of smallholders, and so reaching nearly 50,000 households and over 175,000 beneficiaries via various scaling-up strategies (Muthuri et al. 2021a). We also enhanced capacity in agroforestry of over 10,000 stakeholders through targeted, gender-responsive training. And we identified important value chains for fruit trees and timber in the 3 countries to improve farmers' livelihoods and income.

Other key outcomes were enabled by our provision of context-appropriate land and water management options, development of an innovative agroforestry curriculum guide for tertiary academic institutions in eastern Africa and creation of a sustainable grazing platform in Ethiopia. In response, the government of Ethiopia has elevated agroforestry to a directorate in the newly established Ministry of Environment and Forests. In Rwanda, the government supports tree growing by private investors and smallholder farmers as a means of creating a green economy, which has been enhanced by the development of the National Agroforestry Strategy and Action Plan (2018–2027). And in Uganda, the government is also actively supporting the integration of trees with farming systems (Muthuri et al. 2021b).

Our team's modelling capability, knowledge and understanding of agroforestry was improved through research undertaken in the 5 long-term trials established, and through development of an agroforestry component within the APSIM (Agricultural Production Systems sIMulator) model leading to the development of the APSIM Next Generation model with the capability of modelling agroforestry systems – this was not possible using the APSIM crop model. The Interactive Suitable Tree Species Selection and Management Tool for East Africa was also developed.

Introduction

Over 110 million people in Ethiopia, Rwanda and Uganda depend upon smallholder farming practised across 25 million ha of land. Smallholders generally focus on subsistence, use low levels of external inputs, depend on rainfall rather than irrigation and have limited market access. Most rural households are resource poor, food insecure and vulnerable to climate change. This situation is compounded by population growth (3% per year across the region) and an increased demand for food, water and energy, coupled with declining farm productivity, over-exploitation of trees in agricultural landscapes, and deforestation.

A recent systematic review on the role of agroforestry in improving livelihoods and carbon sequestration in East Africa revealed that agroforestry contributes to livelihood improvement mainly through fodder, food (fruit and nuts), firewood and income, while storing an average of 24.2 ± 2.8 tonnes of carbon per ha in biomass and 98.8 ± 12.2 tonnes of carbon per ha in soil (Muthuri et al. 2023). Therefore, incorporating the right trees in the right contexts on farms can play a critical role in enhancing livelihoods and systems' productivity in addition to reducing land degradation and building resilience to climate change.

Our project, entitled Trees for Food Security, had 2 phases. In the first phase (June 2012 – November 2016), through participatory trials we showed that the establishment of a greater diversity of trees on farms was essential for enhancing food security and improved livelihoods. Through the participatory trials approach, farmers are engaged from the design stage of the agroforestry technologies, through testing and eventually adoption, which is critical for ownership and sustainability. This approach was further strengthened by enhancing the supply of quality tree-planting materials and accompanying infrastructure through the establishment of 5 rural resource centres (RRCs) in Ethiopia (2), Rwanda (2) and Uganda (1) (Muthuri et al. 2017). As a result, during this phase, stakeholders testified as to the benefits of the project. They emphasised the need to reach more farmers at different sites and contexts, and the need to address the challenges and barriers to scaling, including markets. Their feedback encouraged us to initiate a second phase (January 2017 – June 2021) aimed at achieving widespread adoption of appropriate, locally adapted agroforestry practices in key agricultural landscapes in Ethiopia, Rwanda and Uganda. Aligned as it was with national priorities and plans aiming to improve food security and smallholder livelihoods, the project benefited from high-level government support in all 3 countries (Muthuri et al. 2021b). World Agroforestry (ICRAF) led the implementation of both project phases with several partners including national, international, development and academic institutions.

Our research informed a shift in policy by the governments of all 3 countries towards promoting agroforestry options that are appropriate to the broader context and of higher quality, with strong focus on enhancing and scaling up the RRC model for supplying better quality seedlings than before.

In Ethiopia, some of the government's key recent strategies and policies that are well aligned to the project are:

- the Climate-Resilient Green Economy strategy, which considers the integration of trees into farms and landscape as one of its main pillars
- Ethiopia's plan to restore and plant trees across 22 million ha by 2025
- the Agricultural Development Led Industrialization strategy which regards agroforestry as one of the main inputs to transforming rural commercialisation
- The Second Growth and Transformation Plan (GTP II: 2016–2020) in which the government demonstrated the importance of participatory farmer trials and the appraisal of local knowledge in determining locally suitable agroforestry options.

In Rwanda, where farms comprise 85% of all land, the project aligned to several strategies:

- Vision 2020 (Republic of Rwanda 2000) aims to increase tree cover on farms (from 20% to 30%) for the delivery of improved agroforestry products and services. The strategy, jointly managed by the Rwanda Natural Resources Authority and the Ministry of Agriculture and Animal Resources, is to establish agroforestry systems on 85% of farms and reach the target of 30% of farmland covered by trees. For these targets to be achieved, farmers need ready access to high-quality seedlings, and efficient extension services and networking needs to be established across the country. The Trees for Food Security project widened the range of tree species being promoted for different purposes through farmer participatory trials and informed the government's decision to prioritise support for sustainable supply of quality planting materials for enhanced tree growing on farms (Republic of Rwanda 2013).
- Under the Economic Development and Poverty Reduction Strategy (Republic of Rwanda 2013), the integration of trees on farm is one of the options recommended for restoring landscapes and improving resilience to climate change, to develop the agriculture sector.
- In support of creating a 'green economy', the government is involving the private sector in tree planting, through nursery construction and seedling production.

In Uganda, the project aligned well to the following agricultural, forestry and agroforestry sector policies:

- National Agriculture Policy (Republic of Uganda 2013b)
- Agriculture Sector Development Strategy and Investment Plan (Republic of Uganda 2010a) plus the succeeding Agriculture Sector Strategic Plan 2015/16 – 2019/20
- Uganda Strategic Investment Framework for SLM (2010–2020) (Republic of Uganda 2010b)
- National Agricultural Advisory Services (NAADS) Act 2001
- Rangeland Management and Pastoralism Policy (2013)
- Uganda Vision 2040 on reversing deforestation and increasing forest cover
- the National Development Plan, aimed at increasing the contribution of forestry to gross domestic product and to livelihoods
- the National Forest Plan on promoting farm forestry (Republic of Uganda 2013a)
- Uganda Forestry Policy (Republic of Uganda 2001), the National Forestry and Tree Planting Act (2003), and the 2014 draft national forestry and tree planting regulations.

Theory of change

The Trees for Food Security project's theory of change (Figure 9-1) was based on the premise that addressing the research and knowledge gaps identified in the first phase of the project, and scaling up the key lessons learned, would:

- accelerate farmers' adoption of new technologies to better manage trees on farms and in farming landscapes
- promote new marketing strategies
- raise awareness of financial options that could enhance tree-based value chains.

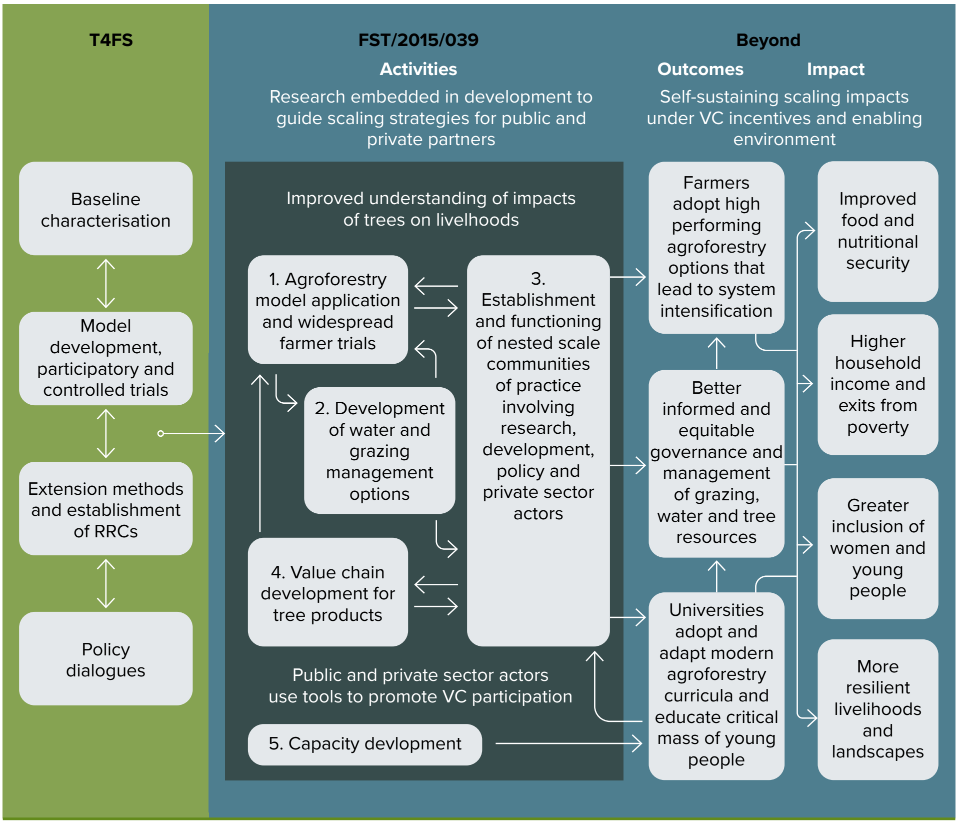

Figure 9-1: **The Trees for Food Security project's theory of change**

RRC = rural resource centre VC = value chain

During the second phase of the project, we reached over 48,000 households, including smallholders and other stakeholders, across the 3 countries. Our 5 objectives for achieving the widespread adoption of appropriate locally adapted agroforestry practices were to:

- enhance knowledge about the impact of tree-cover change on crop productivity, water, nutrients and livelihoods
- integrate appropriate water management technologies and sustainable grazing options in combination with the promotion of agroforestry
- establish locally adaptable options for best practice agroforestry
- examine smallholders and other market actors' ability to participate effectively and profitably in tree-product value chains
- strengthen the capacity of academic institutions in developing and implementing innovative agroforestry curriculums.

Approach to research and development

The project aimed to embed agroforestry research within development initiatives of the target countries. We sought buy-in from both national and local governments to ensure wide adoption and sustainability. Diverse sets of information (biophysical, economic, social factors) across several spatial and temporal scales were integrated and synthesised, from field and farm to district and landscape. We used systematic planned trials and participatory scenario development and modelling to accelerate the positive impacts of the applied research by matching tree management options and associated market and policy interventions to different sites and circumstances.

Scaling up of agroforestry adoption was progressed by assessing 'best fit' options and knowledge gaps for the target agroecology in each country and was adapted using a combination of methods – long-term farmer participatory trials, knowledge dissemination, curriculum development, and training. Where farmers were interested in agroforestry, these methods were used at a range of scales that integrated the promotion of tree diversity with effective learning about what management options work in different places.

In response to research findings on key research gaps from the first phase of our research, we integrated into our research specific components on water management, controlled grazing, access to credit, and value-chain development. Grassroots institutions, such as farmer groups and cooperatives, were strengthened to ensure significant uptake of agroforestry innovations among smallholder farmers, including women and young people. Advocacy research was undertaken to identify factors and policies that support effective cross-sector engagement in developing and promoting locally relevant and sustainable agroforestry options (Muthuri et al. 2021b).

In addition, options to scale up agroforestry adoption included enhancing smallholders' market access for high-value tree products (including fruits, timber and fuelwood); coupling firewood and fodder production with control of livestock grazing; and managing water to ensure tree survival and crop productivity. Moreover, the second phase aimed at scaling up 'best fit' options in the 3 countries with additional support from the governments and additional focus on agroforestry in the relevant national policies.

Participatory trials

A total of 5,036 participatory trials were established in Ethiopia (1,933), Rwanda (2,290) and Uganda (813). In this participatory approach, farmers are engaged from the design stage in testing and eventually adopting the agroforestry technologies. The approach acknowledges that farmers choose only those technologies that appear the most useful and/or profitable for their specific conditions. According to Coe et al. (2014), delivering new technologies is risky if research processes are not well designed.

To mitigate this risk, we set up farmer participatory trials aimed at testing agroforestry innovations on farmers' fields before sharing information about the innovations more widely. Collectively, farmers, researchers and practitioners would observe the results and gain an objective view of the technology's performance. Technologies were adjusted to suit the farmers' needs, making them more relevant and sustainable. Moreover, the trials provided a learning platform for other farmers, who observed and learnt about the new technologies, and eventually tried them on their own farms. Coe et al. (2014) further assert that such an approach minimises the risk of overreliance on a few successful case studies.

Long-term research trials on station and on farm

Complementing the farmer-managed participatory trials, we also collected biophysical data on farms (Buyinza et al. 2019, 2023; Toib et al. 2021) and from 4 existing long-term agroforestry trials in Ethiopia and Rwanda (established in the first phase) (Muthuri et al. 2017), and one in Uganda (established in the second phase). The trials across all the countries and sites were laid out in a randomised complete block design comprising the following treatments:

- a monoculture for each of the species selected in that site and crop (for example, if 4 species were selected, each formed a treatment)
- a mixture of the selected species and crop (mixed tree species plus crop)
- a sole crop treatment (depending on suitable crops, which could also vary with the season).

Where land was available, the following 2 additional treatments were also incorporated:

- a monoculture tree species only
- a mix of tree species only; where land was limited this was achieved by not planting the crop in half of the tree treatments (split plot).

These treatments were replicated 3 to 4 times and the tree species choice was based on site appropriateness and popularity with farmers.

In Ethiopia, the trials were established at Melkassa Station at a semi-arid site and at Bako Agricultural Research Centre in a humid area. The Melkassa and Bako trials each comprised 4 tree species – *Faidherbia albida*, *Moringa stenopetala*, *Acacia nilotica* and *Cordia africana* at Melkassa and *Cordia africana*, *Grevillea robusta*, *Croton macrostachyus* and *Acacia abyssinica* at Bako (Tadesse et al. 2021). Teff (*Eragrostis tef*) was planted at both sites, and maize and finger millet were also planted at Bako in some seasons.

In Rwanda, the trials were established in Karama and Tamira RAB research stations in semi-arid Bugesera and humid Gishwati (in Rubavu district) respectively. The Tamira trial comprised *Alnus acuminata* and *Croton megalocarpus* trees species with crops of maize or potato, depending on the season. At Karama, the tree species were *Grevillea robusta* and *Faidherbia albida* as exotic tree species and *Markhamia lutea* as an indigenous species (Mukuralinda et al. 2018), combined in twos as shown in Figure 9-2. The crop was either maize or beans depending on the season.

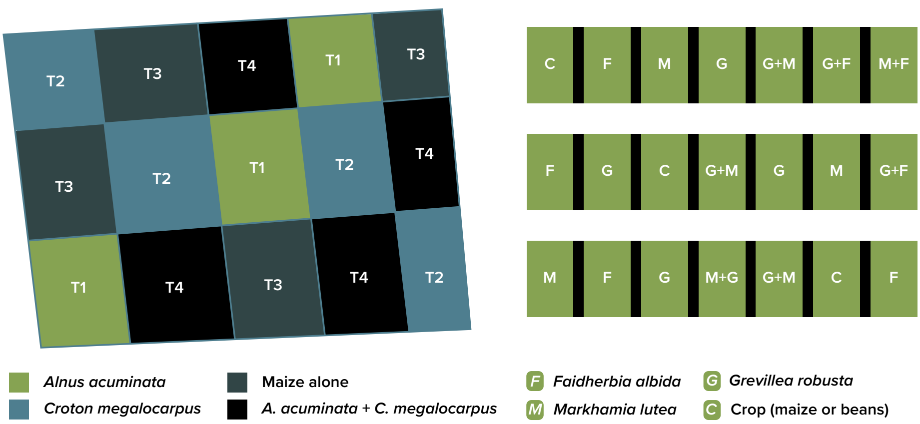

Figure 9-2: Experimental design in Tamira (left) and Karama (right), Rwanda

In the 4 trials in Rwanda and Ethiopia, the trees were also managed through shoot-pruning data collected on tree and crop performance and growth, and other physiological measurements such as sap flow (collected via sap flow gauges from ICT Australia), soil moisture (collected via soil moisture probe) and light interception (collected via ceptometer).

In Uganda, the trial was established at the research station of the National Agricultural Research Organisation in Bulambuli district. The tree species were *Cordia africana*, *Grevillea robusta*, *Albizia coriaria* with beans, and a control of beans alone (Galabuzi et al. 2018).

Key results and discussion

In recognition that farmers are cautious of the technologies offered to them and choose only those technologies that appear the most useful and/or profitable for their specific conditions and needs, we enhanced engagement with farmers and other relevant stakeholders during this phase from the outset. This approach to engagement was based on lessons learnt from the 1,600 trials set up in the first phase in 2014 (Rwanda and Ethiopia) and in 2015 in Uganda (Muthuri et al. 2017) to help strengthen and expand the network of farmers participating in the trials during this phase. These trials were aimed at testing, co-learning and improving/refining agroforestry innovations on farmers' fields and homesteads to encourage adoption using context-appropriate and evidence-based scaling approaches. Therefore, additional participatory trials for the second phase of the project were established from June to December 2017 across the 3 countries following the approach used in phase 1 (Derero et al. 2020). A total of 5,036 participatory trials were established in Ethiopia (1,933), Rwanda (2,290) and Uganda (813) (Muthuri et al. 2021b). It is important to note that across the 3 countries the participatory trials for fruit trees provided a strong foundation for fruit tree value chains (avocado, tree tomato, apple and mango) studied in this project.

Participatory trials in Ethiopia

In Ethiopia, the trials included fruit trees, multipurpose trees, apple rootstock, sustainable grazing options and multipurpose trees with rainwater harvesting (Gebretsadik et al. 2019) at homesteads and on farm plots. Papaya, improved mangoes and coffee were planted in semi-arid areas and improved avocados and *Grevillea robusta* were planted in subhumid areas. Data was collected on the survival, height growth and crown diameter of planted seedlings. Survival and growth scenarios across the locations were compared.

The impact of watering on the growth and survival of multipurpose tree species was also reported. In East Shewa (Adamitulu), farmers reported that they watered seedlings either weekly (43%) or bi-weekly (23%). In Dugda, 77% of the participants watered their papaya seedlings daily and 33% watered theirs bi-weekly. In Lome, farmers mostly watered their seedlings bi-weekly (44%) while 42% watered weekly. Tree survival results in the semi-arid area indicated a relatively higher survival of papaya seedlings in Lome (47.4%) compared to 27.8% at Dugda and 30.9% at Adamitulu.

We also learnt from adopting a farmer-led approach that the actual tree species planted may not fully reflect the farmers' priorities, depending on the availability of tree seeds or fruit tree seedlings from nurseries at planting time. Differential survival between species and niches meant that the connection between desired and realised tree diversity was further reduced. The overall mean survival rate of the seedlings in both the semi-arid and the subhumid areas was 45.6% (±32.6) at 6 months and 33.6% (±25.5) at 14 months (Derero et al. 2020).

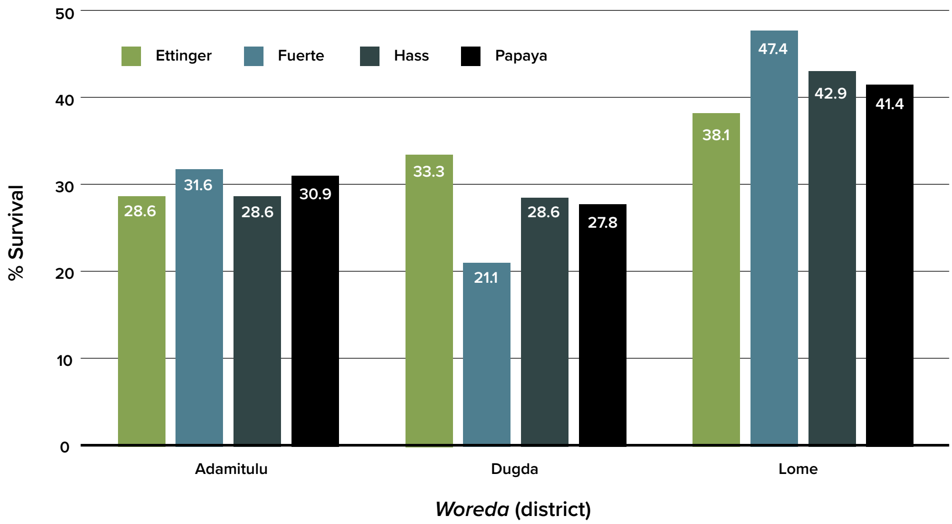

Figure 9-3: Survival rate (%) of planted seedlings at homesteads in Adamitulu, Dugda and Lome, Ethiopia

Our findings further revealed that farmers in Ethiopia have an interest in high species diversity. Their tree species preference was determined by the availability of space; whether the tree species was in stock; ease of tree protection and care after planting; the challenges that free grazing poses to seedling survival and growth; and potential conflict with neighbours. Understanding the species and planting niche (where the trees are in relation to, for example, the boundary, homestead, fence) preferences of farmers combined with appropriate seedling supply and management required is important for increasing the diversity of trees in farmed landscapes (Derero et al. 2020).

Participatory trials in Rwanda

In Rwanda, the trials consisted of 4 main types, namely: i) stakes for climbing beans (a big limitation to climbing beans cultivation in Rwanda), ii) fruits for nutrition and income (tree tomatoes, mango, avocado and papaya), iii) biomass incorporation and iv) soil conservation and erosion control (Mukuralinda et al. 2019).

On fruit trees for nutrition and income, 3 fruit species (tree tomato, avocado and pawpaw (mountain papaya)) were highest in uptake with survival rate being greater than 85% in Gishwati. In Bugesera, the survival rate of nearly all fruit species was about 75%, with some differences among the fruit species and within the sites. The high survival rates reflect the importance that farmers attributed to fruit trees for nutrition and income generation and, therefore, implementing the required management practices, such as weeding, fencing, watering, and applying fertiliser and pesticide.

The main agroforestry species tested for production for stakes for climbing beans were *Alnus acuminata* and *Acacia angustissima* which were readily available at the RRC for farmers participating in this trial. Climbing beans require strong stakes for high yields. In Rwanda, however, high prices and lack of quality staking materials have hindered the growing of climbing beans. In Gishwati, the use of *Alnus* and *Acacia* stakes harvested from the trial sites increased climbing bean yield from the baseline of 1.3 tonne/ha to 2.0 tonne/ha (Muthuri et al. 2021c).

Participatory trials in Uganda

In Uganda, 813 participatory farmer trials were established across a range of contexts. The trials included trees on farm, soil conservation, river bank stabilisation, fodder banks, fruit orchards and woodlots (Galabuzi et al. 2019). Findings from trials indicated that farmers mainly integrated trees into their coffee plantations because of their evaluation of the benefits of shaded coffee ('attitude'), followed by their beliefs about their own capability ('perceived behavioural control'). This renders attitude and perceived behavioural control as reliable predictors of farmers' tree-planting behaviour, especially in the context of developing countries (Buyinza et al. 2020a).

A study to identify differences in farmers' motivations to adopt agroforestry practices in the Mount Elgon region of Uganda showed that about 40% of the variation in farmers' motivation to integrate trees in their coffee plantations was explained by the significant variables of 'attitude' and 'perceived behavioural control' among those actively participating. However, the neighbours of participating farmers, and farmers who had never interacted with the project, were motivated only by 'attitude' and 'social norms', respectively. Motivation resulting from social pressure was strongest among farmers who had never interacted with the project and, in the absence of project interventions, they rely on peer pressure to drive change in their community. These findings indicate that psychological factors are important influences on a farmer's internal decision-making process about adopting agroforestry technology and can be context specific. The adoption behaviour of smallholder farmers is mainly shaped by existing community social norms and beliefs that tend to promote knowledge exchange, as opposed to conventional knowledge transfer extension approaches (Buyinza et al. 2020b).

Addressing free livestock grazing in Ethiopia

Unrestricted (free) livestock grazing poses a risk to the survival and growth of seedlings and, in the second phase of the Trees for Food Security project, one of our objectives for achieving widespread adoption of agroforestry practices was to integrate appropriate and sustainable grazing options with the promotion of agroforestry.

To improve the food security and nutrition of rural people, and to accelerate the adoption of agroforestry and build a climate-resilient green economy, the government, non-government organisations, donors and communities should prioritise a controlled free grazing system and overstocking through the following actions:

- **More sustainable livestock grazing in Ethiopia:** Options should consider ecological, socioeconomic and cultural contexts supported with appropriate policies, institutions, resources, technology and investments.
- **Technology and management:** Options include research and building capacity to empower the farmers; developing forage; identifying grazing and stocking strategies to improve the use of communal grazing land.
- **Policy, strategy and institutions:** Options include developing and implementing sustainable grazing land-use policies; improving institutional arrangements, such as policies on agricultural taxation and inputs; enhancing and strengthening technology dissemination to farmers, and scaling up successful grazing strategies and agroforestry.
- **Stronger partnerships and coordination among institutions and stakeholders:** A successful partnership enhances the impact and effectiveness of action through combined and more efficient use of resources (Kaimowitz et al. 1998).
- **Socioeconomics and culture:** Options include reviewing by-laws through which farmers administer communal grazing lands and closure areas; making use of traditional associations, including the church and mosque, in developing recommendations to restrict free grazing and integrate agroforestry development.

Rural resource centres for promoting agroforestry and distributing high-quality germplasm

The 5 rural resource centres (RRCs) and the satellite nurseries established by the Trees for Food Security project in Ethiopia, Rwanda and Uganda proved instrumental in the production and distribution of high-quality germplasm, training, and demonstrating agroforestry technologies.

Following research, the project produced high-quality germplasm through the RRCs and satellite nurseries, with 738,100 seedlings produced in Uganda, 1,140,000 in Rwanda and 2,324,026 in Ethiopia. More than 3,400 households in Uganda, 1,700 in Ethiopia and 18,700 in Rwanda benefited from the high-quality germplasm. The species included high-value timber trees such as *Grevillea robusta*, fruit trees, ornamental trees and other multipurpose trees. In addition to tree distribution, the project facilitated training and demonstrations in high-quality germplasm use, tree planting and management, and improved nursery practices.

The RRCs also gave farmers opportunities to share their experiences with their peers and receive technical guidance and other services from public and private extension services. More than 4.2 million high-quality tree germplasms were produced at the RRCs and more than 75% of these were distributed to households across the 3 countries. Moreover, farmers and farmer groups began to establish their own private nurseries after acquiring training from the RRCs. This demonstrates that through the RRCs, the communities not only acquire high-quality tree-planting materials, which have better survival rates, but also receive technical assistance on tree planting and management. This, coupled with the potential for income generation from trees undoubtedly makes agroforestry technologies attractive to farming communities.

In building capacity, our approaches were gender responsive and endeavoured to ensure women and girls benefited from the interventions. In all, 10,347 members benefited from training and demonstrations, with at least a third comprising women and young people. The project also supported 8 doctoral students and 2 master's students.

Ethiopia

In Ethiopia, the Batu and Bako RRCs, established in Ziway and Bako, respectively, became special hubs for widescale dissemination of agroforestry knowledge and high-quality germplasm to end users (Mekuria et al. 2016). The RRCs were technically supported by the project, which provided inputs for producing high-quality planting materials and facilitated training in agroforestry technologies. For example, through the project, an irrigation scheme was installed and, to date, the RRCs have produced more than 2 million tree seedlings, providing more than 1.1 million high-quality planting materials to farmers and the government through the Green Legacy Initiative.

Owing to production of high-quality germplasm at the RRCs, a generally high tree survival rate was recorded. Survival of fruit trees such as *Psidium guajava*, *Carica papaya*, and *Persea americana* was above 50% in most sites. This high rate of survival could be attributed to the farmers' watering practices for fruit trees, introduced to them through the participatory trials, and indicates that with enhanced post-tree management practices, higher survival rates of trees can be achieved.

Rwanda

In Rwanda, the 2 RRCs of Karama and Karago facilitated production of quality fruit and multipurpose tree species as well as disseminating agroforestry knowledge (Mukuralinda et al. 2016). Another 14 RRCs were established – 10 in Mulindi and one each in Bugesera, Kayonza, Gatsibo and Nyagatare.

The project also partnered with community-based groups and farmer cooperatives to establish satellite nurseries that produce high-quality tree germplasm for distribution to the wider community, including schools, churches and health centres. During the second phase of the project, the RRCs and satellite nurseries – supported by World Vision Rwanda and IMBARAGA farmers organisation – produced and distributed 1,019,965 seedlings with a value of US$128,820.

The satellite nurseries provided employment and generated substantial income to their farmer members, enabling them to buy assets such as land, build or rehabilitate houses, or pay for health insurance and school fees.

In Rwanda, every last Saturday of the month is set aside for community work, commonly known as *Umuganda*. In its second phase, the project used *Umuganda* as a platform to bring people together to plant trees on communally agreed sites. *Umuganda* became a means of distributing seedlings and promoting tree planting for conserving soil and controlling erosion. A total of 4,056 farmers were reached through *Umuganda*.

Uganda

In Uganda, Mbale RRC increased farmers' access to good-quality tree germplasm materials. The RRC and other tree nurseries run by community groups produced about 417,000 high-quality tree seedlings of various fruit and multipurpose tree species. The seedlings were distributed to farmers, churches and schools for planting to increase tree cover, for agroforestry products and for land restoration. The RRC also serves as a hub where farmers and the wider community can access a range of agroforestry reference materials and technical advice (Okia et al. 2016).

The project was at the forefront of building the capacity of tree-seed dealers, nursery operators and smallholders to identify sources of high-quality tree seeds, manage pests and diseases, and upgrade production standards for seedling quality and tree germplasm.

Insights about the factors affecting agroforestry adoption by women and young people in Uganda, indicate that land scarcity, seed shortage, lack of a market and limited technology were among the challenges identified (Figure 9-4). Positive incentives for adoption included farmer training and capacity building, a rising demand for tree products and access to free seedlings. Other strategies involved linking tree planting to climate change mitigation and to reversing deforestation impacts, and promoting fast-growing tree species (Galabuzi et al. 2021).

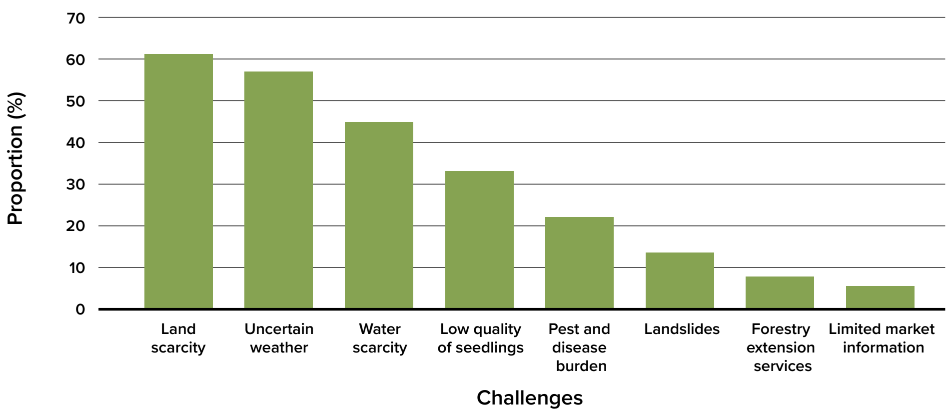

Figure 9-4: Factors affecting adoption of agroforestry by women and young people in Uganda

Value chains

We identified country-specific tree value chains and financing options that could be useful for smallholders growing:

- avocado, mango and apple in Ethiopia
- avocado and timber in Uganda
- tree tomato in Rwanda.

Avocado value chain – Ethiopia

In Ethiopia, findings from an assessment of fruit tree value chains and related financing options conducted by the project team indicated that producers were aware of which fruit trees are preferable for cultivation and which fruit trees suit the climatic conditions (Mawia et al. 2018). Avocado was the most preferred because it does well in both subhumid and semi-arid areas such as West and East Shewa. The demand for avocado was and continues to be high, but farmers were not able to meet the growing demand because of inadequate water and limited knowledge about tree production and management. Mango, on the other hand, is well adapted in Bako, although, due to white mango scale insect pest, its production and consumption has decreased. In the Tigray region, the survey results showed that apple production is viable because of its ecological suitability and the rising demand. Most farmers were self-funding, with only a few farmers obtaining credit from financial institutions.

Farmers, traders and processors reported an existing demand for all these fruits, which suggests that fruit production has a high potential for income gain. However, in Oromia and Tigray regions smallholders' lack of knowledge and other market actors' inability to participate effectively and profitably in tree-product value chains were raised as barriers.

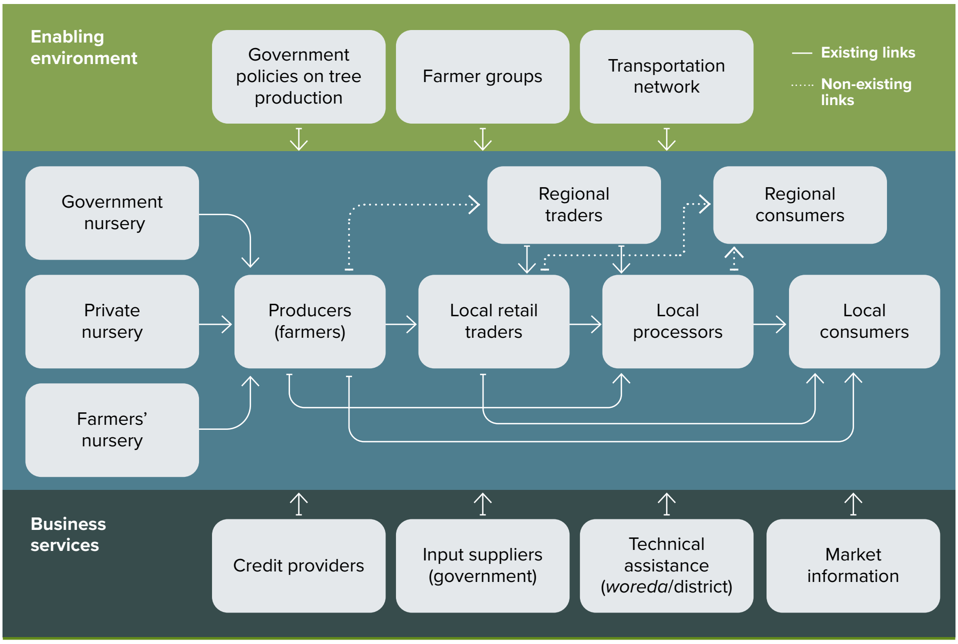

Figure 9-5: Value-chain map for avocado in the Bako region of Ethiopia

For avocado, the preferred market channel was direct to consumers because they purchase consistently, although the amounts are small. While traders buy in bulk, they offer lower prices, deducting costs such as storage and transport. Avocado is produced by farmer groups as well as individual farmers.

Farmers reported a growing unmet demand for avocado owing to lifestyle changes locally and regionally. While most of the business services in the value chain (Figure 9-5) were reported as being available in the *woredas* (districts), farmers in a group discussion expressed concern that such services were unavailable or unsatisfactory. For instance, the Agriculture Growth Program in Bako is one of the government programs that disseminates information about new technologies in avocado production. The program, however, does not reach most of the farmers in the *woreda* since it has a specific mandate to work mainly in only some *kebeles* (a *woreda* is comprised of several *kebeles*, or municipalities). In addition, while technical advice is provided by the *woreda* agricultural office, advisory services on agroforestry practices are not readily available or are not part of the package provided by the development agents. Farmers reported that they relied on buyers for market information on product prices and quality attributes.

Mango value chain – Ethiopia

Two main market channels for mango were identified as from producer to consumer and from producer to local trader. Although underdeveloped, the mango value chain in the *woreda* of Adami Tulu Jido Kombolcha has the potential to grow owing to increasing demand for mangoes and mango juice. However, the supply in the *woreda* is very low, with many traders obtaining mangoes from the southern region. In areas such as Ziway, the scarcity of water means few farmers can manage to produce and sell mangoes locally to consumers. Cultivation of fruit trees in general is not considered a priority due to water shortages, especially in the dry seasons. However, with improved water harvesting and capacity building in management of fruit trees, farmers could be expected to take up mango production in Adami Tulu Jido Kombolcha.

According to key informants such as traders and processors, interventions should focus on increasing mango production, particularly the grafted type, to meet huge unmet demand due to population increases and lifestyle changes.

Apple value chain – Ethiopia

Agroecological conditions in Tsaeda Emba are suitable for apple production. Apples trees are more resistant to pests, diseases and frost, which are major setbacks to fruit production in this district. Moreover, apple trees mature after 3 years, unlike the fruits currently under production, such as avocados and oranges, which take up to 7 years and are highly susceptible to frost damage. Farmers in Tsaeda Emba mentioned that they expected the benefits from apples to include increased nutrition and financial gain. Producers reported that apples have high productivity, with a single apple tree yielding as much as 20 kg of fruit in a single season if well maintained. Consequently, a farmer with 10 trees can earn as much as 7,000 Ethiopian birr (ETB) (US$250) in a production season. One of the major challenges facing apple production in Tsaeda Emba was lack of adequate planting materials.

Farmers harvesting apples in this region reported selling directly to consumers only. No traders or processors were identified for the apple value chain in this region. It was reported, however, that institutions such as World Vision Ethiopia and World Agroforestry, as well as the government, were very supportive in providing seedlings, technical advice and training on apple production. In the one year that the farmers were producing apples, the Trees for Food Security project subsidised the cost of the seedlings.

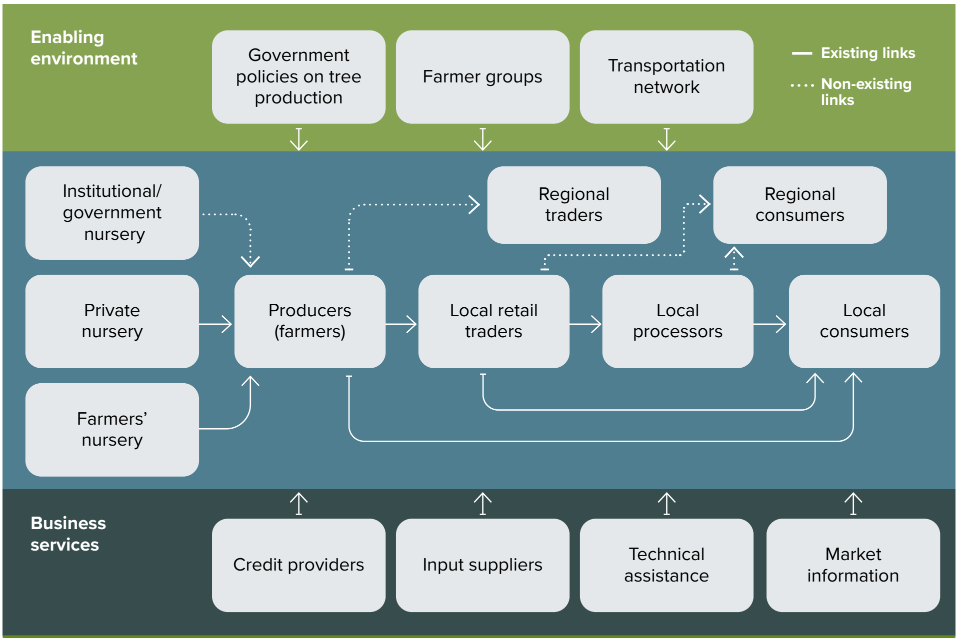

Figure 9-6: **Value-chain map for mango in the *woreda* (district) of Adami Tulu Jido Kombolcha, Ethiopia**

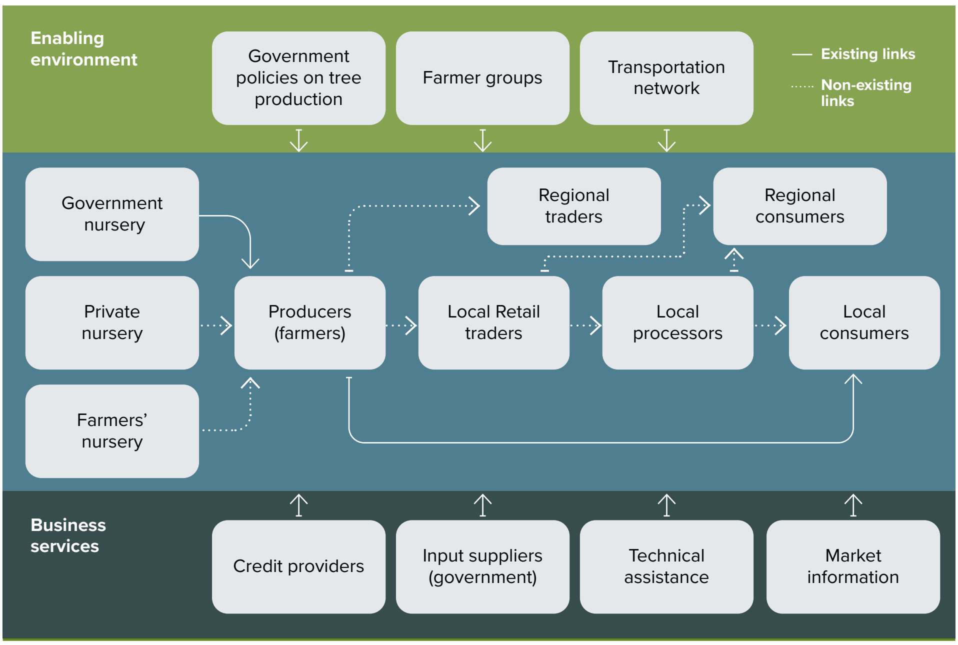

Figure 9-7: **Value-chain map for apples in the *woreda* (district) of Tsaeda Emba, Ethiopia**

Avocado and timber value chains – Uganda

In Uganda, avocado and timber were identified as the potential tree-based value chains for development (Sekatuba et al. 2019). Avocados produced by farmers are sold to both large-scale and small-scale traders. The timber value chain has several actors, including tree farmers, timber brokers, traders and transporters. Other actors include timber processors (loggers and carpenters), consumers of semi-processed materials and consumers of finished products. Demand and research knowledge is increasing for both value chains. There is growing interest from financing institutions in tree growing as a viable enterprise.

Most of the tree-based enterprises accessed financial services from savings and credit cooperatives societies, followed by self-funding, microfinance institutions and, lastly, commercial banks. Cooperative societies were preferred to other sources because they are less stringent in their requirements when issuing loans and their interest rates are lower compared to commercial banks.

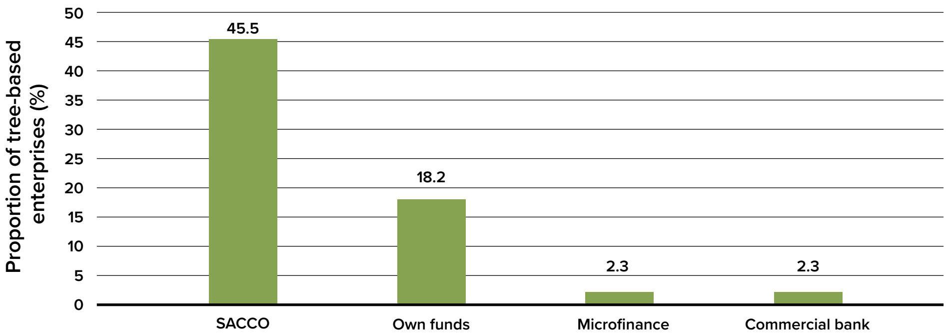

Figure 9-8: Financing options used by tree-based enterprises in the Eastern Highlands of Uganda

SACCO = savings and credit cooperative society

While private financing mechanisms are more suited for tree-based enterprises, which are largely informal, small scale and long term in nature, their downside is that the cost of capital is very high, reducing the profit margin. Other constraints include skills and knowledge gaps, lack of a subsidy system for tree-based enterprises, and risks relating to credit, production and marketing of tree-based products.

Tree tomato value chain – Rwanda

To shape the tree tomato industry in Rwanda for the benefit of smallholder farmers and the Rwandan economy at large, it is critical to understand the industry's competitive forces and their underlying causes. A study was conducted to determine factors that influence the competitiveness of the tree tomato value chain and propose strategies that could help to improve it in Rwanda (Solange 2021). Factors hampering the tree tomato value-chain competitiveness in Rwanda were reported as the bargaining power of suppliers (63% of interviewees); the bargaining power of buyers (58.43%); the severity of the threat of new entrants (22.28%); the intensity of rivalry among existing key competitors (65.60%); and the severity of the threat of imported produce, especially from neighbouring countries such as Tanzania (71.74%).

The strategies proposed to improve the competitiveness included better linkage between the actors as a means of reducing transaction costs, improving integration along the value chain and increasing farmers' technical know-how. The formation of farmer cooperatives will also give a voice to the farmers. Furthermore, potential buyers could spell out product criteria to help ensure supply consistency.

The tree tomato value chain in Rwanda faces strong rivalry from Tanzanian imports. Such competition can spur innovation, which could in the long run make the Rwandan tree tomato industry more competitive.

The project's impact on adoption of promoted agroforestry practices and tree species

Impact assessment results from Rwanda for the Trees for Food Security project indicate that there was a significant increase in the percentage of farmers in the project sites taking up promoted agroforestry practices such as planting trees, using high-quality germplasm, grafting, and incorporating green biomass, such as the leaves of *Alnus acuminata or Gliricidia sepium*, into the soil. In phase 1 sites of the project that continued engagement in phase 2, households were 15% more likely to take up at least one promoted agroforestry practice (p=0.023) and 8% more likely to grow any of the promoted tree species.

Except for tree tomatoes, this significant increase in uptake was observed only in phase 1 sites (meaning those that had continued to phase 2), which suggests that the learning curve for agroforestry practices may be long. It would therefore seem that farmers require considerable time to learn, test and adapt the practices to suit their context before applying them on a large scale.

Key lessons from the impact assessment in Rwanda

Below are the 3 key findings from the project's impact assessment in Rwanda (Oduol et al. 2021).

The impact of agroforestry interventions can be maximised through well-designed and targeted scaling approaches

In Rwanda, the percentage of households that our survey reached was small (30%), so gains from agroforestry interventions could be increased by improving breadth and depth of reach in the 3 districts (Bugesera, Nyabihu and Rubavu). Where low exposure rates are reported, the first key step should be to review and restructure the program delivery to scale out new ideas and technology. However, we also recognise that random sampling design meant that every farmer in the selected villages had an equal chance of being interviewed, which may have contributed to more non-project farmers than project farmers (those who participated in the trials) being interviewed. Consequently, mechanisms for targeting and testing options over a wider population of farmers would help achieve the breadth required to realise impact at scale.

Long-term gains from agroforestry interventions could be maximised by fostering adoption at scale

The results from the impact assessment study conducted in Rwanda were inconclusive on productivity and welfare outcomes, both for the phase 1 households and the overall sample. Therefore, a well-designed and targeted scaling strategy that seeks to address context-specific constraints to adoption is critical. Such scaling strategies should aim to achieve a high multiplier effect and include mechanisms that encourage behaviour change among households, such as reducing the financial and technical constraints that limit adoption of agroforestry.

Effective implementation of such a strategy depends on the presence of development partners and scaling stakeholders with the skills and expertise to connect with the farmers' unique challenges. Where developmental outcomes are anticipated, the scaling stakeholders should be identified and involved right from the project inception phase, with clearly defined targets for each stakeholder, including the scaling pathway, to maximise adoption.

A different sampling and impact estimation approach is needed

Given that agroforestry interventions take time to manifest and may not have proven detectable from the population sampled for the impact assessment study in Rwanda, modelling must be used to attempt to consider likely impacts more than 10 years beyond the project implementation phase. The endline data was collected 3 years into the actual implementation or scaling phase; as such, it will be critical to further interrogate data for economic and environmental impacts using ex-ante modelling approaches.

Economic impacts

In all 3 countries, project interventions reportedly led to improved livelihoods for participating farmers. As a result of the project, the potential for tree-based value chains to increase income was identified in all 3 countries.

Uganda

In Uganda, the use of *Calliandra* spp. as fodder for livestock and beekeeping boosted milk and honey production. As a result, farmers' income increased and they no longer travelled long distances to collect stakes, fuelwood and animal feeds.

Arising out of the Trees for Food Security project, the Nkoma Youth Development Association established a commercial tree nursery where they raise and sell assorted fruit and multipurpose tree seedlings. The project provided potting bags, shade mats, watering cans and seeds to start them off.

'The trainings opened our eyes not only on the numerous benefits of trees, but also on tree nursery operations and management. We applied what we learnt to start and run a tree nursery as business', explained Bashir Wapaya, Chairperson of Namanyonyi Youth Group.

The young people have raised more than 9,000 seedlings of various species and have so far sold and expanded their capital investment to 3,610,000 Ugandan shillings (UGX) (about US$960). Group members managed to access small loans from their savings to meet their immediate social needs, such as paying school fees and medical expenses and buying food. They invested in improved seed and hoes and other inputs. Efforts were made to link the group to microfinance institutions to access bigger loans.

Testimonies from farmers in Bududa indicated that they were aware of the economic benefits that agroforestry can bring. One farmer, Waninga Noah, reported:

> After I prune my grevillea trees, I get firewood for home use and more for sale. I sell a bundle of firewood at 2,000 Ugandan shillings. Recently, I sold 6 bundles of firewood [earning about US$3] and managed to buy maize seeds for planting.

Some farmers have started receiving carbon credits from ECOTRUST at the rate of US$6–US$8 per tonne of carbon. The money is paid in 7 instalments (over a 10-year period) until the tree is 25 years old. So far, 27 farmers have been paid.

In Uganda, *Calliandra* spp., avocado and timber were identified as potential tree-based value chains. Avocado is produced by the farmers and sold to both large-scale and small-scale traders, while the timber value chain has several actors, including tree farmers, timber brokers, traders and transporters. Other actors included timber processors (loggers and carpenters) and consumers of semi-processed materials and of finished products. Opportunities for developing both value chains are based on a high demand for tree seedlings; the increasing need for research knowledge; and growing interest from institutions in financing tree growing.

Ethiopia

In Ethiopia, the Margarissa group at Batu RRC was legally organised during the project's second phase and obtained a taxpayer's number as an identification by the district (*woreda*) revenue and tax administration office. The group continues to be actively engaged in producing improved planting materials of avocado, mango, papaya, multipurpose tree seedlings and ornamental plants. In addition, farmers are benefiting from the sale of tree seedlings in both Batu and Bako RRCs. The group members recorded an income of more than ETB265,000 (US$6,400) from nursery operations and the sale of high-quality germplasm. Currently, they earn a net income of about US$200 per month from the RRC operations.

Similarly, a group of 11 young people took over management of the Bako RRC activities. Under the leadership of the project coordinator in Bako and the Head of Agriculture and Natural Resources for Bako Tibe district, the group continues to work at the RRC, producing tree seedlings which they have distributed for trials and tree planting activities. In 2019, the group earned an income of ETB25,000 (US$600), mainly from the sale of coffee seedlings and banana suckers.

Rwanda

In Rwanda, farmers reported substantial income from growing tree tomatoes, incorporating biomass into the soil and using stakes to support climbing beans (Cyamweshi et al. 2019). Since the successful scaling out of tree tomatoes in Bugesera, farmers from the Bugesera Innovation Platform have managed to plant more and have earned income from selling the fruits, seeds and seedlings. More farmers are now investing in tree tomato production to meet rising market demand.

One such farmer, Emmanuel Tuyireze, started with only 500 tree tomato seedlings. His first harvest yielded one tonne of tree tomato fruits, which he sold at the market (at 500 Rwandan francs (RWF) per kg), earning about US$600. Tuyireze has now increased his plantings to nearly 8,700 plants and owns a nursery where he raises and sells seedlings to the farmers. The income accrued from tree tomatoes has enabled him to buy additional land where he grows diverse crops.

Twagiramungu Vianney is another champion farmer at Mareba sector, Bugesera district. He has planted 116 tree tomatoes and, at maturity, he was harvesting 20 kg of fruit per week, which he sold to his neighbours and at the local market. Towards the end of 2019, he reported earning income of RWF230,000 (US$250) after only a few months of harvest (Ndayambaje et al. 2021).

After acquiring knowledge and skills on nursery management, tree planting and management via the project, 10 farmer groups entered into collaborative agreements with the Forest Landscape Restoration Program, where they were contracted to produce tree seedlings in nurseries. In addition, those initial farmers who began growing fruit trees from the project have started earning income from the sale of fruit. In 2020, a farmer group from Nyamata sector signed a contract for RWF8 million (US$8,695) with the National Agricultural Export Development Board to produce fruit.

Farmers in Rwanda have also benefited from green manure, as illustrated by several testimonies.

Maniriho Beatrice from Nyundo sector:

> I have been in this project for 3 years. Before the project, I used to cultivate crops using farmyard manure only and the productivity was very low.
>
> When I joined the project, we were trained on how to mix leaves with soil for green manure and combine it with chemical fertilisers. We were also trained that we can use green manure if chemical fertiliser is not available. I was further trained on using Alnus stakes for climbing beans.
>
> After implementing those practices, crop production has increased, and I am able to adequately feed my family.
>
> On my 20 m × 20 m field, I used to harvest 25 kg of beans. Now I harvest almost 50 kg after using green manure. I also learnt that trees and crops can grow together on the same field.

Nyiramahirwe Joselyne from Karago sector:

> I have been in the project for 2 years. I have learnt about the use of fertiliser and planting 2 seeds in a hole as opposed to the 4 to 5 seeds that I was planting before.
>
> I have also been trained on the use of stakes from Alnus. Now I am able to use less stakes, so more land is utilised for planting seeds. With the use of green manure, the land remains fertile for a long time. My land area is 40 m × 15 m. I used to plant 40 kg of bean seeds and harvest 100 kg; now I use 7 kg of seeds and harvest 170 kg.

In addition, tree tomato and grevillea value chains were identified as having potential. Given the scope of our project, we focused on developing these value chains at the farmers' level. Opportunities for further development of the tree-based value chains are expected to be taken up with national development partners, the private sector or funders.

Social impacts

Improved participation in agroforestry-related activities among communities, including women and young people, was observed in all project sites. As of June 2021, the Trees for Food Security project had directly reached nearly 50,000 participants in the 3 countries (Muthuri et al. 2021a).

Given the lag in agroforestry impacts, we carefully designed scaling strategies that respond to smallholder farmers' widely held myth of 'seeing is believing'. Strategies included peer-to-peer learning and evidence-based approaches such as participatory trials, demonstrations and field days. Gender integration was a focus with an emphasis on women and young people. In all 3 countries, we tried to ensure that gender-balanced groups are involved in running operations at the RRCs, cooperatives and farmer groups. At least a third of project activities included women and young people.

Co-learning and sharing experience among farmers through participatory trials and RRC activities led to widespread adoption. In Ethiopia, the participatory trials approach was adopted by the Integrated Watershed Development and Productive Safety Nets Program, which is financed by the World Bank in its activities. In addition, the RRC approach was adopted by a project to create women- and youth-centred green jobs, a project which is funded by the Packard Foundation.

Changes in behaviour and farmer practices were observed. In Rwanda, 2 agroforestry options for tree tomatoes and climbing beans were scaled out from the subhumid areas of Gishwati to the semi-arid areas of Bugesera. The project introduced tree species such as *Acacia angustissima* and *Vernonia amygdalina* as alternatives to stakes for climbing beans in Rubavu district. These fast-growing trees improve soil fertility through biomass incorporation, nitrogen fixation and soil erosion control, and they reduce the distance travelled by farmers to collect stakes.

We leveraged Rwanda's monthly community work concept of *Umuganda* to introduce agroforestry's crucial role, bringing together farmers, local authorities and diverse stakeholders to plant trees on sites that they selected. Messages on tree management and species as well as sustainable land management were disseminated. *Umuganda* was also used as a means of distributing seedlings and promoting tree planting for soil conservation and erosion control, especially at Karago and Nyundo.

In Uganda, awareness about tree-based enterprises among women and young people has increased. Establishing tree nurseries and beekeeping became popular among these groups as a source of income generation.

In Tigray, Ethiopia, apple production was successfully adopted as a worthwhile intervention. According to the participating farmers, apple production is seen as potentially profitable because, unlike other fruits, apples have proven more resistant to pests and diseases and frost. Moreover, apples mature after 3 years whereas the fruits currently being produced in the area, such as avocados and oranges, take up to 7 years to mature and are highly damaged by frost.

The project had significant spillover effect, with agroforestry best practices being continually adopted by farmers who were not involved with the project. Here is a comment by a farmer in Nakatsi, Uganda:

> Only a few fruit trees planted by our grandparents were remaining prior to the Trees for Food Security project, and these few trees were susceptible to overuse in terms of pruning for fuelwood by the wider community. After the project created awareness on tree planting and benefits of trees, more people took up tree planting and the pressure on the few trees that were there has reduced.

At the national level, the RRC model is now seen as a pathway for creating youth employment. The RRCs established by the project will continue as hubs for capacity development and distribution of high-quality germplasm, as well as sources of livelihood for the young people and women working at the centres (Carsan et al. 2021). The coming together of farmers in cooperatives has continued to empower them and provide forums for peer learning and suitable platforms for developing the tree value chain.

Not only did farmers use the technical skills they gained, but they were also observed innovating and adapting practices to better suit their specific sites and contexts. This indicates that farmers' ways of thinking were broadened and the project opened their eyes to other techniques. For example, after being trained on grafting fruit trees in nurseries, farmers went ahead and successfully grafted trees planted on their own farms.

Environmental impacts

As a result of participatory trials and tree planting initiatives, at the project sites we saw increased tree planting and protection, wider species diversity, and higher quality germplasm established. About 4.2 million multipurpose seedlings were produced from the 5 RRCs and satellite nurseries across the 3 countries. Of these, more than two-thirds were distributed for community plantings. Species promoted by the project provided fodder, fences, firewood, poles, timber, food and fruits, as well as services such as soil and water conservation, erosion control, riverbank stabilisation, improved soil fertility and carbon sequestration (Muthuri et al. 2021b).

In Rwanda, stakeholders other than farmers also engaged in tree planting initiatives. Schools, churches and health centres were mobilised to plant trees on their individual and communal lands. The planting of multipurpose tree species such as *Alnus acuminata, Acacia angustissima* and *Gliricidia sepium* helped improve soil fertility and reduce erosion. At the same time, these trees are increasing tree cover, hence contributing to local microclimate moderation and carbon sequestration (Cyamweshi et al. 2021). In the Gishwati site, agroforestry trees planted on terraces strengthened erosion control structures. Tree growing and terracing combined with sustainable farming practices reduced siltation in newly established model villages in Lake Karago in Nyabihu district. Agroforestry promotion was in keeping with the government's nutrition-sensitive agriculture policy where each household is expected to plant at least 3 fruit tree seedlings (Ndayambaje et al. 2021).

In Uganda, beans and tomatoes are commonly grown crops in the Mount Elgon region. Both crops require staking for support during flowering to enhance yields. However, lack of stakes had hindered production, with high post-harvest losses in the case of beans. To help smallholder farmers overcome the staking challenge, we provided seedlings of fast-growing tree species such as *Calliandra calothyrsus, Alnus acuminata, Eucalyptus* spp. and *Melia volkensii*. Stakes were obtained by pruning and thinning woodlots, with thinnings and prunings offering other benefits such as soil fertility improvement, livestock fodder and fuelwood (Galabuzi et al. 2021).

In Ethiopia, a higher tree survival rate was recorded in Tigray compared to other sites. This could be attributed to the considerable effort to raise awareness of tree protection and management practices. Survival rates of 73% for apple, 74% for guava and 75% for coffee were recorded in November 2019 (Gebretsadik et al. 2021).

Through the project, an interactive tool was developed for selecting and managing suitable tree species for eastern Africa, including for Rwanda (Kuria et al. 2017b), Ethiopia (Kuria et al. 2017a) and Uganda (Kuria et al. 2020). This web-based tool aids in understanding tree diversity and its contribution to livelihoods and landscape health, and promotes the right tree for the right place for the right purpose. Users can easily access information based on tree species, suitability of their agroecological zone, tree products, environmental services, origin (native or exotic) or niche. The tool also provides specific details on the trees' biophysical growth conditions and management requirements, and links to other agroforestry databases.

This tool will be developed as a mobile phone application, accessible to extension providers and local communities as a guide on suitable tree species and management practices matched to specific sites.

The modelling capability of people designing agroforestry layouts, including considering species and functionality options for simulating tree-crop interactions and yields, was enhanced by their use of the APSIM Next Generation frameworks. APSIM's range of tree-crop models is continually increasing (Smethurst et al. 2017; Dilla et al. 2018, 2020).

With the RRCs and satellite nurseries established and capacity development on tree planting and management continuing, we expect the production of high-quality tree germplasm to result in higher tree survival rates. Benefits from the trees planted are expected to accrue in the next 5 years and beyond, as maturing trees yield products and services. Furthermore, positive results from the tree–crop water interactions will not only encourage farmers to adopt trees on farm, but also encourage proper management practices. Continued adoption of agroforestry and soil and water conservation practices will help to build resilience to climate effects, especially prolonged drought. Evidence exists of soil erosion control in project areas, especially in the sloped lands, and this is also contributing to better crop yields.

Conclusions

As a result of the farmer participatory trials that incorporated the local context and circumstances, greater understanding of farmer-led agroforestry options in the 3 countries was achieved in phase 2 of the Trees for Food Security project. The trials enabled findings to be shared and encompassed farmer-generated innovations. Long-term trials allowed for an improved understanding of tree-crop interactions of different species in different contexts, and enabled data collection and analysis of tree growth, crop yields, biomass and soil samples. Research results demonstrated the importance of management practices, such as improving water use efficiency through tree pruning, while application of green manure led to soil nutrient cycling lifting crop productivity.

Mapping site-specific land and water management led to identification of cost-effective water management practices across a range of sites. A total of 184 maps depicting land types and suitable interventions were completed and shared with partners and stakeholders during train-the-trainer sessions. The maps were integrated in the partners' plans to guide future development of technologies for managing land and water.

Discussions on existing policies and strategies relating to grazing management concluded that the problem of free livestock grazing in Ethiopia could be sustainably addressed through the design of locally specific options that address ecological, sociocultural and economic contexts. Subsequently, a sustainable grazing platform for the Tigray region was formed (Kiros et al. 2018) and a policy brief offered sustainable grazing policy recommendations.

The project's establishment of 5 RRCs and 18 satellite nurseries (cooperative, group or individual) across Rwanda, Ethiopia and Uganda proved instrumental in the production and distribution of quality germplasm of key tree species. Other benefits include the promotion of previously ignored native species, training and demonstration of agroforestry, creation of job opportunities and provision of avenues for farmers to share experiences with their peers, as well as receive technical guidance and other services.

The project identified potential country-appropriate value chains for tree products, which improved the ability of smallholders and other market actors to participate effectively and profitably in these value chains. This led to the identification of tree value chains for tree tomatoes in Rwanda, avocado in Ethiopia, and timber and avocado in Uganda, along with country-appropriate financing options. Further, an impact assessment conducted in Rwanda concluded that there was a significant increase in the percentage of households taking up various agroforestry practices. In fact, growing demand for agroforestry was evident across all project sites.

In the second phase of the project, a regional agroforestry curriculum guide was developed after a comprehensive assessment of agroforestry curriculums and extension training from universities and technical colleges. This innovative curriculum guide is useful for harmonising and enhancing the quality of training in tertiary institutions, while ensuring agroforestry is offered as a comprehensive course integrating all the relevant components.

References

Buyinza J, Muthuri C, Downey A, Njoroge J, Denton M and Nuberg I (2019) 'Contrasting water use patterns of two important agroforestry tree species in the Mt. Elgon region of Uganda', *Australian Journal of Forestry*, 82:57–65, doi:10.1080/00049158.2018.1547944.

Buyinza J, Muthuri CW, Denton MD and Nuberg IK (2023) 'Impact of tree pruning on water use in tree-coffee systems on smallholder farms in Eastern Uganda', *Agroforestry Systems*, 97:953–964, doi:10.1007/s10457-023-00842-2.

Buyinza J, Nuberg IK, Muthuri CW and Denton MD (2020a) 'Psychological factors influencing farmers' intention to adopt agroforestry: a structural equation modeling approach', *Journal of Sustainable Forestry*, 39:854–865, doi: 10.1080/10549811.2020.1738948.

——(2020b) 'Assessing smallholder farmers' motivation to adopt agroforestry using a multi-group structural equation modeling approach', *Agroforestry Systems*, 94:2199–2211, doi:10.1007/s10457-020-00541-2.

Carsan S, Dembele C, Mukuralinda A and Muthuri C (2021) 'Rural resource centers provide extension support for diversified food production options', in Atta-Krah K, Chotte JL, Gascule C, Gitz V, Hainzelin E, Hubert B, Quintero M, Sinclair F (eds) *Agroecological transformation for sustainable food systems: insight on France-CGIAR research,* 26, Agropolis International, Montpellier, France, doi:10.23708/fdi:010082500.

Coe R, Sinclair F and Barrios E (2014) 'Scaling up agroforestry requires research "in" rather than "for" development', *Current Opinion in Environmental Sustainability*, 6(2014):73–77.

Cyamweshi RA, Kuyah S, Mukuralinda A and Muthuri CW (2021) 'Potential of Alnus acuminata based agroforestry for carbon sequestration and other ecosystem services in Rwanda', *Agroforestry Systems*, 95:1125–1135, doi:10.1007/s10457-021-00619-5.

Cyamweshi RA, Muthuri WC, Mukuralinda A and Kuyah S (2019) '*Alnus acuminata*: an effective fertilizer tree for smallholder farmers in sub-humid regions of Rwanda' [conference poster], in Dupraz C, Gosme M and Lawson G (eds) *Book of abstracts: 4th World Congress on Agroforestry*, 20–22 May 2019, Montpellier, France, CIRAD-INRA, pp. 345.

Derero A, Coe R, Muthuri C, Hadgu KM and Sinclair F (2020) 'Farmer-led approaches to increasing tree diversity in fields and farmed landscapes in Ethiopia', *Agroforestry Systems*, doi:10.1007/s10457-020-00520-7.

Dilla A, Smethurst PJ, Parsons D, Barry K and Denboba M (2018) 'Potential of the APSIM model to simulate impacts of shading on maize productivity', *Agroforestry Systems*, 92(6):1699–1709, doi:10.1007/s10457-017-0119-0.

Dilla AM, Smethurst PJ, Huth NI and Barry KM (2020) 'Plot-scale agroforestry modeling explores tree pruning and fertilizer interactions for maize production in a Faidherbia parkland', *Forests*, 11(11):1175, doi:10.3390/f11111175.

Fantaye SK, Hadgu KM, Birhane E, Haile M, Muthuri C, Mowo GJ, Georgis K and Negussie A (2019) 'Sustainable grazing options for enhancing accelerated scaling ups an impacts of agroforestry innovations in Ethiopia', [conference presentation] in Dupraz C, Gosme M and Lawson G (eds) *Book of abstracts: 4th World Congress on Agroforestry*, 20–22 May 2019, Montpellier, France, CIRAD-INRA, p. 258.

Federal Democratic Republic of Ethiopia (2016) *Second growth and transformation plan (GTP II: 2016-2020)*, National Planning Commission, Addis Ababa, Ethiopia.

——(2011) *Climate-resilient green economy strategy*, Environment Protection Authority, Addis Ababa, Ethiopia.

Galabuzi C, Agaba H and Okia C (2018) *Trees for Food Security-2 Project semi-annual report*, National Forestry Resources Research Institute, Kampala, Uganda.

Galabuzi C, Agaba H, Okia CA, Odoul J and Muthuri C (2021) 'Women and youths participation in agroforestry: what counts and what doesn't around Mount Elgon, Uganda?', *Journal of Mountain Science*, 18(12):3306–3320, doi:10.1007/s11629-021-6812-5.

Gebretsadik W, Kinuthia R, Tadesse S, Hadgu K and Muthuri CW (2021) *Trees for Food Security-2 Project: Ethiopia highlights*, project brief, World Agroforestry, Addis Ababa, Ethiopia.

Kaimowitz D, Byron RN and Sundertin WD (1998) 'Public policies to reduce inappropriate tropical deforestation', in Lutz E, Binswanger H, Hazell P and McCalla A (eds) *Agriculture and the environment: perspectives on sustainable rural development*, World Bank, Washington, DC, USA, pp. 303–322.

Kiros S, Kiros MH, Hagazi N and Haile M (2018) *Terms of reference (ToR) for the establishment of sustainable grazing platform in Tigray: for exploring options on legal recognition and enforcement of traditional grazing bylaws for accelerating adoption of agroforestry*, not published.

Kuria, A, Buyinza J, Galabuzi C, Muthuri C, Agaba H, Okia C, Kwateng-Yeboah C, Kinuthia R, Wamaitha M, Carsan S, Lamond G and Sinclair F (2020) *Suitable tree species selection and management tool for Uganda*, [Database], World Agroforestry, Kampala, Uganda.

Kuria A, Dawit S, Endale Y, Derero A, Iiyama M, Muthuri C, Hadgu, K, Kinuthia R, Betemariam E, Asantewaa M, Muriuki J, Kindt R, Dedefo K, Senbeto M, Njenga M, Lamond G, Pagella T and Sinclair F (2017a) *Suitable tree species selection and management tool for Ethiopia*, [Database], World Agroforestry, Addis Ababa, Ethiopia.

Kuria A, Uwase Y, Mukuralinda A, Iiyama M, Twagirayezu D, Njenga M, Muriuki J, Mutaganda A, Muthuri C, Kindt R, Betemariam E, Cronin M, Kinuthia R, Migambi F, Lamond G, Pagella T and Sinclair F (2017b) *Suitable tree species selection and management tool for Rwanda*, [Database], World Agroforestry, Kigali, Rwanda.

Mawia H, Oduol J, Kinuthia R, Seid H, Tedesse S and Muthuri C (2018) *An assessment of market potential of fruit tree value chains and financing options for fruit production in Ethiopia*, report for ACIAR project 'Trees for food security – 2' (FST/2015/039), World Agroforestry, Nairobi, Kenya.

Mekuria A, Carsan S, Kiptot E, Derero A, Hadgu K and Muthuri C (2016) *Batu Rural Resource Centre: a community based approach to deliver agroforestry technologies to rural farmers*, [brochure], World Agroforestry, Addis Ababa, Ethiopia.

Mukuralinda A, Carsan S, Muthuri C, Kiptot E, Kuria A and Mwangi A (2016) *Karama and Karago Rural Resource Centres: a new approach to delivery of Agroforestry technology in Rwanda*, [brochure], World Agroforestry, Butare, Rwanda.

Mukuralinda A, Ndayambaje JD, Bucagu C, Mugayi A, Gafaranga J, Cyamweshi, Musana B, Mujawamariya P and Sensoga A (2018) *Trees for Food Security-2 semi-annual technical report*, not published.

Muthuri C, Kinuthia R, Kuria A and Njoki C (2021a) *Trees for Food Security-2 Project: overview and achievements*, project brief, World Agroforestry, Nairobi, Kenya.

Muthuri C, Mukuralinda A, Derero A, Okia C, Buyinza J, Hadgu K, Nkurunziza C, Kinuthia R, Smethurst P, Baudron F, Kiptot E, Masikati P, Iiyama M, Kuria A, Tanui J, Tenge N, Bernard M, Mowo J and Sinclair F (2017), *Trees for Food Security Project: final report*, final report for ACIAR project 'Improving sustainable productivity in farming systems and enhanced livelihoods through adoption of evergreen agriculture in eastern Africa - Trees for food security' (FSC/2012/014), ACIAR, Canberra.

Muthuri C, Njoki C, Kinuthia R, Mukuralinda A, Gebretsadik W, Galabuzi C, Ndayambaje JD, Kuria A, Oduol J, Smethurst P, Tadesse S, Malesu M, Kung'u J, Hadgu K, Mugunga C, Girmay A, Kiros S, Masikati P, Carsan S, Buyinza J, Okia C, Birhane E, Isubikalu P, Seid H, Mugayi A, Sekkito I, Micheal S, Gafaranga J, Toib A, Tofu A and Sinclair F (2021b) *Trees for Food Security Project 2: final report*, final report for ACIAR project 'Developing integrated options and accelerating scaling up of agroforestry for improved food security and resilient livelihoods in Eastern Africa - Trees for food security – 2' (FST/2015/039), ACIAR, Canberra.

Muthuri CW, Kuyah S, Njenga M, Kuria A, Öborn I and van Noordwijk M (2023) 'Agroforestry's contribution to livelihoods and carbon sequestration in East Africa: a systematic review', *Trees, Forests and People*, 14:100432, doi:10.1016/j.tfp.2023.100432.

Muthuri CW, Mukuralinda A and Sinclair F (2021c) 'Tree stakes for climbing beans in Rwanda', in Atta-Krah K, Chotte JL, Gascule C, Gitz V, Hainzelin E, Hubert B, Quintero M and Sinclair F (eds) *Agroecological transformation for sustainable food systems - Insight on France-CGIAR research,* no.26, Agropolis International, Montpellier, France.

Ndayambaje JD, Mukuralinda A, Njoki C, Niyitanga F, Bambe JC, Kinuthia R, Kuria A and Muthuri C (2021) *Trees for Food Security-2 Project: Rwanda highlights*, project brief, World Agroforestry, Nairobi, Kenya.

Oduol J, Mukuralinda A, Ndayambaje JD, Kinuthia R, Mugambi J, Gakwavu T, Bambe JC, Mugayi A, Gafaranga J, Kuria A and Muthuri C (2021) *Impact assessment report, Rwanda*, World Agroforestry, Nairobi, Kenya.

Okia C, Buyinza J, Agaba H, Carsan S, Kiptot E, Muthuri C (2016) *Mbale Rural Resource Centre: a community-based approach to deliver agroforestry technologies to rural farmers in Eastern Uganda*, [brochure], World Agroforestry, Kampala, Uganda.

Republic of Rwanda (2013) *Economic development and poverty reduction strategy II (2013-2018)*, Republic of Rwanda, Kigali, Rwanda.

——(2000) *Rwanda Vision 2020*, Ministry of Finance and Economic Planning, Kigali, Rwanda.

Republic of Uganda (2001) *Uganda forestry policy*, Ministry of Water, Lands and Environment, Kampala, Uganda.

——(2010a) *Agriculture sector development strategy and investment plan: 2010/11-2014/15*, Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

——(2010b) *Uganda strategic investment framework for sustainable land management 2010 – 2020*, Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

——(2013a) *National forest plan 2011/12–2021/22*, Ministry of Water and Environment, Kampala, Uganda.

——(2013b) *National agriculture policy*, Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

Sekatuba J, Nansereko S, Kwaga P, Sekitto I, Wherikhe G, Okia C, Wabwire DM, Galabuzi C, Kimenya G, Mudondo S, Agaba H and Oduol J (2019) *Contests, prospects and strategies for enhancing performance of avocado and timber value chains in Mt. Elgon, Uganda,* not published.

Smethurst PJ, Huth NI, Masikati P, Sileshi GW, Akinnifesi FK, Wilson J and Sinclair F (2017) 'Accurate crop yield predictions from modelling tree-crop interactions in gliricidia-maize agroforestry', *Agricultural Systems*, 155:70–77, doi:10.1016/j.agsy.2017.04.008.

Solange G (2021) *Determinants of competitiveness of tree tomato value chain in Rwanda* [master's thesis], University of Rwanda.

Tadesse S, Gegretsadik W, Muthuri C, Derero A, Hadgu K, Said H and Dilla A (2021) 'Crop productivity and tree growth in intercropped agroforestry systems in semi-arid and subhumid regions of Ethiopia', *Agroforestry Systems*, 95:487–498, doi:10.1007/s10457-021-00596-9.

Toib AA, Muthuri CW, Gebrekirstos A, Hadgu K, Njoroge J, Sinclair F and Fetene M (2021) 'To prune or not to prune *Faidherbia albida*: competing needs for water, wheat and tree products in semi-arid Ethiopia', *Agroforestry Systems*, 95:1661–1673, doi:10.1007/s10457-021-00675-x.

Chapter 10

Improving community-forest productivity in the arid regions of Nusa Tenggara islands and central Java, Indonesia

Aris Sudomo, Ryke Nandini,
Muhammad Hidayatullah, Dewi Maharani,
I Wayan Widhana Susila and Aulia Perdana

Abstract

Developing timber and non-timber forest product (NTFP) value chains so that farmers capture more value from their products is a key strategy to improve livelihood opportunities, but these opportunities are constrained by silvicultural management practices that result in low productivity and profitability from integrated timber and NTFP production systems. This is compounded by smallholders and communities lacking a combination of market access, processing capacity and appropriate business models that could realise value from their products.

There is huge potential to tackle rural poverty in much of Indonesia through developing more productive and profitable smallholder timber and non-timber production systems. Combining tree planting with management of non-timber species has proven an important part of farmers' livelihood strategies, but generally at low levels of productivity. While opportunities exist for better-fit production practices, achieving such integration faces significant difficulties in the poorer, more arid regions in the western Nusa Tenggara islands and Gunungkidul in central Java. In this chapter, we present several case studies in these areas.

Figure 10-1: **Map showing case study sites in central Java and the western Nusa Tenggara islands**

Candlenut – Batudulang village, Sumbawa Island

Batudulang, a village in the middle of a community forest in the western part of Sumbawa Island, is a candlenut (*Aleurites moluccana*) producing area, which is evident along the main road many kilometres before reaching the village. Most trees are in their productive period of 20 to 30 years. The Batudulang people were originally shifting cultivators who planted various types of local rice. Farmers also plant corn and cassava to meet their daily needs. In 1987, residents began cultivating candlenut trees on their private land or private forest. Seeing that these efforts were successful and prices were beginning to improve, people began to plant more candlenut trees.

Batudulang is one of 6 villages in Batulanteh subdistrict, with a population of only 851 people. Most of the residents of Batudulang are Indigenous people, from the Sumbawa tribe, and a small number are from the Bima and Sasak tribes. Their main source of income is farming, cultivating candlenut, coffee and fruit agroforestry systems.

The village has abundant natural resources. Community forests produce coffee and candlenut using agroforestry practices and these are the main source of income for the community. Coconut, jackfruit, avocado, papaya, guava and mango enrich the potential of the community's economic resources. Candlenut trees grow well on the community-owned land, which is located at an altitude between 250 m and 800 m above sea level, with average rainfall of 1,000–1,900 mm/year for the period 2009–2019 (BPS Kabupaten Sumbawa 2019).

Candlenut was chosen as an agroforestry species because it has a long productive period. Candlenut derived from seed can bear fruit at the age of 3 or 4 years old, while those from vegetative material (grafts) begin to bear fruit at the age of 2 years old. Candlenut productivity continues to increase at the age of 20 years and will only decrease after about 70 years. Trees are planted with a spacing of 10 m × 5 m or with a density of 200 trees per hectare (ha) and can produce about 80 kg of candlenut per tree per year (Krisnawati et al. 2011c).

In Batudulang, candlenut is generally planted with a spacing of 8 m × 8 m or 10 m × 10 m, as per the cultivation guidelines from the Ministry of Agriculture. This wide spacing allows farmers to practice agroforestry with other crops. Several types of plants are found in candlenut-based agroforestry, including bamboo (*Bambusa* sp.), soursop (*Annona muricata*), coconut (*Cocos nucifera*) and doat (*Syzygium polyanthumi*).

It is almost impossible to find flat plains large enough to cultivate paddy or corn in Batudulang's mountainous topography. Timber and non-timber forest products are the main source of livelihoods of the community. When candlenut was introduced to the village, there were no planting guidelines and farmers used their local wisdom to plant candlenut using agroforestry practices. Most farmers planted candlenuts using a wide enough spacing so that they could plant other species in between. As a result, farmers cultivated corn between the small candlenut plants, but nowadays, as trees get older and the canopy gets wider, the space for intercropping is narrowing. However, we can still see selected understorey species, such as ginger, lemongrass and chilli. These 3 types of plants are usually planted simultaneously in separate plots in the understorey. Tubers are also common understorey species (Hamdani and Susanto 2002; Murniati 2016, 2020). The dominant candlenut agroforestry pattern can be applied until the tree is between 30 and 50 years old and can be combined and managed simultaneously with other plantation crops, such as cocoa and coffee (Armas, Dassir and Millang 2020). Thus, farmers can still develop the understorey ensuring that the potential added value of agroforestry activities is maintained.

The candlenut tree generally flowers once a year, but the flowering season lasts about 3 months. In Batudulang, the candlenut flowering season is between July and September and harvesting is done from October to December every year. Candlenut harvesting is done by picking up the fruit that has fallen to the ground, 2 to 4 times a month. It is done by farmers with family members or using workers who are paid based on the number of candlenut harvested, the rate being US$0.068/kg. According to Batudulang farmers, a single tree that has reached the age of 20 years can yield as much as 200–300 kg/year, or an average of 15 tonne/ha/year. This is in line with Duke (1983) who mentioned that candlenut production ranges from 4 to 20 tonnes/ha/year. If the price of candlenut is at the collector's level, US$0.47/kg, then one candlenut tree can produce about US$95–US$142/year or about US$7,118/year/ha. The economic value is higher if the candlenut is processed into candlenut oil, which currently sells at US$1.69 for 60 ml.

Figure 10-2: (a) Candlenuts before deshelling in Batudulang village, Sumbawa Island, Indonesia; (b) Candlenuts drying under the sun in Batudulang village, Sumbawa Island, Indonesia; (c) Collecting candlenut shells for post-harvest processing in Batudulang village, Sumbawa Island, Indonesia

Credit: Muktasam Abdurrahman (a and c) and Aulia Perdana (b)

Most of the candlenut produced from Batudulang is marketed to meet household-scale needs at the local level (mostly West Nusa Tenggara Province). However, it is also marketed outside the region and to other islands, especially Bali and West Java (Sahidu et al. 2018; Siddik et al. 2018).

So far there are 2 small-scale businesses producing candlenut oil in Batudulang, each with a processing capacity of about 30–40 kg of candlenut per month. The oil processing still uses simple pressing machines. The limited production capacity means that the marketing process for candlenut oil is still on a domestic scale in the Sumbawa and Lombok islands, although it is also sold online for about US$1.60/60 ml. Support and synergy between business actors and relevant stakeholders are expected to increase production capacity and marketing reach in the future.

Box 10-1: Agroforestry in action at Batudulang village

Farmers in Batudulang village in Sumbawa Island are practising agroforestry with species including teak, suren (Toona sureni), and candlenut along with food crops such as corn. The women of the village commonly process the candlenuts, as well as honey, turmeric and ginger. When farmers clear land for corn, they always leave some trees to prevent erosion and water loss. Batudulang village is upstream of the lowland of Sumbawa and acts as the water source. Women and men are more likely to share the tasks when they work together on their own land, compared to when they use hired labourers. In the case of hired labour, women are hired to pick candlenuts and men to clear the area surrounding the trees. Nut picking is done more frequently than clearing. Candlenuts are harvested about 7 months a year.

Endah and Intan, local women farmers, told how they work as labourers every day until noon, mostly to pick up nuts from the ground. Sometimes they do other labour tasks, such as cleaning up the grass, or planting chilli and corn. They have done this work since they were 15 years old, which means that they did not graduate from high school. Even if they had some land of their own with various tree species, this work gives them additional income. Endah said, 'There is other income, but candlenut brings money the quickest. After we pick up from the field, we can earn money right away.'

Most farmers do not stock or process candlenuts while they wait for a higher price. Many must sell immediately since it is part of their daily income. Annually, a candlenut tree produces 30–80 kg of nuts. After shelling, the nuts weigh 25% of the original weight and sell for US$0.74–1.85/kg. Like many others in Indonesia, candlenut farmers in the village usually do not try to innovate. They have acquired their farming techniques from their parents and lack access to specialist knowledge. Farmers compared the difference in revenue between selling whole or processed nuts: 10 kg of whole nuts could be sold for about US$3.00 whereas dried deshelled nuts sold for about US$4.50 and the shells for US$0.26. If the farmers processed the nuts themselves rather than paying others to do so, the revenue for 10 kg of processed nuts is US$1.74 more than the revenue for 10 kg of whole nuts.

Honey, ginger and turmeric are other sources of livelihoods for the villagers. Honey is obtained from wild bees and it has become an icon of this village. The community works in groups to collect honey sustainably from the forest area and community forests or gardens. Local women entrepreneurs commercially manage honey from this village. Bu Junaidi is one of them. She and her all-women team established a home business extracting and packaging honey, and marketing the end product through the Sumbawa Forest Honey Network to neighbouring cities. Where the household income totalled around US$1,000 a month, 20% would come from honey. The neighbouring community of Brang Pelat used to collect wild honey from the forest, but between 2015 and 2016 they established 600 stingless beehives in the village and began selling honey in Sumbawa and Lombok. The chairperson of the community cooperative, Pak Juraidin, mentioned that they have generated US$1,879 in revenue from honey sales in the past year and these funds are shared between the 120 households that belong to the cooperative. Local women in neighbouring hamlets also processed turmeric and ginger into instant herbal drinks. The production has reached 11 tonnes and 1.4 tonnes, respectively, from an average of 2 ha of land. Of the total turmeric production, about 5–6 tonnes are sold at a price of US$0.16/kg, while the remaining 5 tonnes is processed into instant herbal drinks.

Understorey plants

Ginger is an understorey plant often grown with candlenut. It is widely chosen because cultivation techniques are relatively easy and yields are high. At the start, ginger yields tubers that can reach 10 to 12 times the number of seeds planted, with this number decreasing as the candlenut tree ages. When the candlenut tree is 4 to 6 years old, the ginger yield ranges from 5 to 6 times the number of seeds. The selling price of ginger ranges from US$1.00 to US$1.36 per kg. The economic value of ginger can be increased by processing it into ready-to-drink powder, as done by the Batudulang community.

Figure 10-3: **Ginger yields from a trial plot in Repok Pidendang hamlet, western Nusa Tenggara**
Credit: Ryke Nandini

Figure 10-4: **A farmer harvests ginger in Batudulang village, Sumbawa Island, Indonesia.**
Credit: Muhammad Hidayatullah

Figure 10-5: (Left) Farmers bringing harvested ginger in sacks to the village, Sumbawa Island, Indonesia, and (right) weighing ginger ready for sales and processing

Credit: Muhammad Hidayatullah

Figure 10-6: Ginger is processed into an instant herbal drink by Batudulang village farmer groups, Sumbawa Island, Indonesia.

Credit: Ryke Nandini

Ginger originating from the regency of Central Lombok is marketed not only at the local level, but also for export, especially to European countries such as Germany and the Netherlands. The quality of ginger produced from the island of Lombok is of better quality than that from other regions, and this has led to a high demand for ginger exports. The export demand from a single buyer can reach 40 tonnes a month and, to meet the demand and seize opportunities, suppliers are trialling ginger production at a demonstration plot (Mataram 2020).

Ketak (*Lygodium circinnatum*), a climbing fern, can also be cultivated as an understorey plant, with financial benefits for the community. In Batudulang, ketak often grows naturally beneath candlenut trees. Traditionally, local farmers consider these plants a nuisance and clear them just before the candlenut harvest. However, if managed properly, ketak yields valuable tendril products, suitable for weaving. To alter the farmers' perception, our research project was initiated. The tendril products, bundled in sets of 100, are sold to craftsmen for weaving purposes.

The financial analysis of managing ketak under candlenut stands in Batudulang showed a benefit:cost ratio (BCR) of more than 1 (Susila et al. 2018). The ketak plants in this case are clumps, each with several 3-metre-long vines. Plant management is required to obtain high-quality stems as soon as possible. Labour wages are not included because these farmers (landowners) have been trained to manage the ketak plants.

From one plot, before being managed, there were up to 60 clumps with 1,080 tendril stems and 843 tendrils that could be harvested (78.06%). There were also 254 tendrils from the new shoots that could be harvested out of the total of 293 new-grown shoots. The total cost of managing ketak crops for 15 months in this plot until harvest was US$24.58 (Table 10-1). The total harvest produced 13 bundles with a selling price of US$54.73 and a total cost of US$24.58, giving a BCR of 2.1:1. Selling price calculations are shown in Table 10-2.

Table 10-1: Cost components of growing a 15-month ketak crop under candlenut stands in Batudulang village, Sumbawa Island, Indonesia

Activity	Cost (US$)	Description
Harvesting or pruning the stems	7.02	Fuel for motorbikes
Gathering and planting 40 Gliricidia trunk cuttings (for use as climbing structures to support the ketak vines)	10.54	Pruning vines, planting and transportation
Land maintenance	7.02	Transport to visit plots and weeding
Total	**24.58**	

Table 10-2: Selling price calculations for ketak grown under candlenut stands in Batudulang, Sumbawa Island, Indonesia

Description	Yield (no. of bundles)	Selling price per bundle (US$)	Total selling price (US$)
78.06% of the first harvest	8	4.21	33.68
21.94% of the first harvest	3	4.21	12.63
The remaining 254 tendrils from the new shoots	2	4.21	8.42
Total	**13**	**4.21**	**54.73**

So far, ketak has been considered as a weed and is discarded during land clearing. In un-managed candlenut tree stands and gardens, many tendril stems were found with a length of more than 3 m. But as part of candlenut agroforestry, it can be an additional source of income. Based on research results on ketak grown under candlenut stands in Batudulang, ketak can be harvested as raw material for woven handicrafts at less than 15 months in age, and even less than 12 months at some places, such as the Rarung area of Central Lombok (Susila et al. 2021). Plant management must be carried out regularly, such as pruning, harvesting, providing climbing structures, and clearing weeds and other plants from around the ketak clumps.

According to collectors of woven handicrafts in Beleka village, at the centre of Lombok island, the maximum length for marketing ketak vines to craftspeople and raw material collectors is 2 m. At the collector level, the ketak price ranges from US$3 to US$5 per bundle, with a bundle containing 100 vines of average length 165–170 cm.

Figure 10-7: (Left) Ketak in bundles ready for sale in Batudulang village, Sumbawa Island, Indonesia, and (right) ketak woven into a basket

Credit: I Wayan Widhana Susila

Multipurpose plants

Another type of agroforestry in the Batudulang village area is used to provide shade to coffee crops. The community has planted robusta coffee (*Coffea canephora*), which is known to have many health benefits. The choice of shade tree has been linked to honey from wild bees in the Batudulang area, so bee-feeding trees and nest trees for forest bees are grown as shade trees for coffee plants. Other multipurpose tree species are also grown, such as binong (*Tetramales nudiflora*), rimas (*Duabanga moluccana*), udu (*Litsea accedentoides*), suren (*Toona sureni*), sengon (*Falcataria moluccana*), teak (*Tectona grandis*), dadap (*Erythrina variegate*), avocado (*Persea americana*), mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*) and coconut (*Cocos nucifera*).

As one of the leading plantation sector commodities, coffee has a global market and a highly promising economic value. Yet, coffee production in community forests still tends to be very low because it is not effectively managed – only 0.53 tonne/ha/year (Tania et al. 2019), far below its potential, which can reach 1.2 tonne/ha/year (BPS Batulanteh District 2019). This is also the case in community forests in the Batudulang area, where farmers say that the average coffee production ranges from 600 to 700 kg/ha/year. With the selling price of coffee about US$1.5/kg, the economic value obtained ranges from US$895 to US$1,044/ha/year, with this return sourced by the community simply from fruit harvesting. Economic value could be added by cultivating several understorey plants in the early stages of growing coffee, including ginger (*Zingiber officiale*), citronella grass (*Cymbopogon nardus*), maize (*Zea mays*) and chilli (*Capsicum* spp.).

Mixed-pattern planting – Central Lombok

In the regency of Central Lombok, mahogany (*Swietenia mahogany*), sengon (*Paraserianthes falcataria*), and teak (*Tectona grandis*) are typically chosen for planting on private forest land (Setiawan et al. 2014). Planting occurs in a variety of ways, such as intercropping with food crops and livestock or mixing in different species of multipurpose plants, such as fruit trees (Nandini 2017). Farmers seek out these 3 species because of their reputation for rapid growth, high-quality timber production and high selling prices (Iskandar et al. 2017). With just 32% of Central Lombok's total timber production coming from private forests (Nandini 2017), 2 strategies for increasing the productivity of private forests are agroforestry and the creation of NTFPs (Affandi et al. 2017). According to Diniyati and Achmad (2015), private forests created for the production of NTFPs and for agroforestry systems contributed between 63% and 75% to farmers' income. Moreover, adding an agroforestry system can reduce the risk of crop failure (Paut et al. 2018).

Although agroforestry systems can be established on privately owned forest land using the farmers' chosen plant species and planting methods (Kurniawan and Hidayat 2020; Hernawan et al. 2020), it is essential to assess the compatibility of the species and planting pattern before planting. According to Ahmad et al. (2019), to assess this compatibility several elements should be considered, such as site features (including soil type and rock formation), social factors (such as farmers' attitudes to the plant species), and the plants' capacity to grow at the site.

Figure 10-8: In this agroforestry system in Pemepek village, central Lombok, farmers grow sengon with small taro, ginger and vanilla.

Credit: Ryke Nandini

Farmers in Pemepek village in Central Lombok developed an agroforestry system based on private sengon (*F. moluccana*) forest using 3 plant species – small taro (*Colocasia esculenta*), ginger (*Zingiber officinale*) and vanilla (*Vanilla planifolia* Andrews). Observations revealed that small taro had the highest average survival rate of the 3 plant species examined under sengon stands. A sengon, vanilla and small taro (SVT) pattern exhibited higher survival rates than other planting patterns, such as the sengon, vanilla, and ginger (SVJ) pattern and the sengon, vanilla, ginger and small taro (SVJT) pattern. In the SVT pattern, the survival rate of the small taro was 100%. Even the first planted parent plant had tillers that spread out around it, making the surrounding area lusher.

Observational comparisons revealed that the sengon stands that could produce the most wood were in the SVJT pattern (270.9 m^3/ha), whereas those that could produce the least amount of wood were in the SVT pattern (219 m^3/ha).

Ginger plants grown in the SVJ pattern yielded 140 kg/ha, more than in the SVJT pattern, which yielded just 90 kg/ha.

In contrast to the ginger in the SVJ and SVJT patterns, the small taro grown in the SVT pattern yielded less than the small taro in the SVJT pattern. Compared to the SVT pattern, which yielded 317.5 kg/ha, the SVJT pattern yield was greater (331 kg/ha).

An income analysis revealed that the SVJT pattern, with an additional revenue of US$803/ha/year, outperforms the SVJ pattern at US$380/ha/year, and the SVT pattern at US$538/ha/year (Table 10-3). The added value was 68% higher than the income from the SVT pattern. The comparative potential income from sengon (*F. moluccana*) wood is US$7,422/ha/year (SVT), US$8,909/ha/year (SVJ), and US$9,182/ha/year (SVJT) – based on the current potential of sengon and the assumption that the selling price of *F. moluccana* in West Nusa Tenggara is US$170/$m^3$. When taking all factors into account, the sengon-based agroforestry pattern with a mixture of vanilla, ginger and small taro (SVJT) is argued to be the best pattern for private forest.

Table 10-3: Comparisons of yield and income for mixed patterns of sengon, vanilla, ginger and small taro

Commodity	SVT		SVJ		SVJT	
	Yield	Revenue (US$/ha/year)	Yield	Revenue (US$/ha/year)	Yield	Revenue (US$/ha/year)
Ginger (kg/ha)	-	-	140.0	380	90.0	244
Small taro (kg/ha)	317.5	538	-	-	331.0	559
Sengon (m^3/ha)	219.0	7,422	262.9	8,909	270.9	9,182
Total	**536.5**	**7,960**	**402.9**	**9,289**	**691.9**	**9,985**

SVT = sengon, vanilla and small taro
SVJ = sengon, vanilla and ginger
SVJT = sengon, vanilla, ginger and small taro

Based on the results of our economic feasibility calculation using benefit–cost analysis, for 9-month planting cycles, planting ginger and taro under sengon stands has economic feasibility after the fourth planting cycle (BCR for ginger is 1.37:1), planting small taro has economic feasibility after the third planting cycle (BCR for small taro is 1.47:1), and the mixed pattern has economic feasibility in the second cycle (BCR of 1.08:1)[17].

17 In each planting cycle, the yield from ginger agroforestry is assumed to increase by 50%, small taro by 30%, and mixed crops by 54%, in accordance with the results of a 2-year study.

In West Nusa Tenggara Province, using the assumption of planting 30% each of sengon (*Paraserianthes falcataria*), mahogany (*Swietenia macrophylla*), and teak (*Tectona grand*is) in locations with potential as community forest land, the potential carbon storage for sengon private forest amounted to 3,576 tonnes, mahogany private forest 178,202 tonnes, and teak private forest 12,440 tonnes, while for other species it was 6,253 tonnes (Nandini et al. 2021). While the carbon potential of the sengon private forest was the smallest of the 3, in the long term it is estimated that sengon private forest will contribute to reducing greenhouse gas emissions in West Nusa Tenggara by 26% until 2030, following the commitment contained in t he West Nusa Tenggara Governor Regulation Number 51 of 2012 concerning regional action plans for reducing greenhouse gas emissions.

Within the province, community forest institutions can be established either through project-based forest and land rehabilitation, or via community groups. Top-down project-based community forest institutions usually run only at a low level after project completion. Institutions initiated by community groups in general persist, with some groups even expanding activities, not only related to community forest activities, but also as social institutions. This condition often occurs in Central Lombok.

Two examples are the farmer groups Bumi Lestari and Beriuk Makmur in Central Lombok, which formed following the completion of forest and land rehabilitation projects. Initiated and assisted by forestry extension workers, these groups formed strong institutions and are still running even though the project has ended. Their organisational structure and activities are clearly listed and evaluated regularly. Collective rules (*awig-awig*) are formed and implemented by all members of the groups.

Figure 10-9: *Acacia mangium* is being trialled here as a companion species to teak.
Credit: Dewi Maharani

Intercropping short-rotation timber species with teak – Gunungkidul, central Java

The island of Java constitutes only 6.8% of Indonesia's area but 57.5% of its population. The Gunungkidul district in central Java covers a land area of 148,536 ha (BPS 2019), with a population of 747,161 (BPS 2021). The area of private forest is 42,781 ha (BPS 2019), while that of state forest is 13,826 ha (Balai Kesatuan dan Pengelolaan Hutan Yogyakarta 2014). Most of the land is dry and marginal land with karst rocks, but an area of about 55,627 ha holds high potential for private forest development (Utomo et al. 2021). The reforestation (timber planting) program on dry land in Gunungkidul has produced several private forests since it began in 1970 (Broto et al. 2017). Every smallholder farmer in Gunungkidul has limited land (less than 0.25 ha), with teak (*Tectona grandis*) as the main tree species (Kurniasih et al. 2021).

Gunungkidul is famous as a teak production area, and the species dominates local tree production systems. Teak is a high-value timber species with a rotation age of 20 to 30 years (Roshetko et al. 2009, 2013; Sudomo et al. 2019). Teak is part of the culture, and the community member has pride if they own a house or household appliances made of teak. There are 3 forms of land use in the district – dryland fields (*tegalan*), home gardens (*pekarangan*) for trees and annual crops, and private forests (*kitren*) for producing teak (Sudomo and Maharani 2018). There is also line planting with teak as border trees. The farming community in Gunungkidul applies agroforestry on *tegalans* and home gardens, whereas the tree monoculture pattern is applied to private forests (Oktalina and Hartono 2015; Roshetko and Manurung 2009; Roshetko et al. 2013a; Sudomo and Maharani 2018).

Private forests have important ecological and economic benefits for achieving sustainable forest management. In Gunungkidul, the contribution of wood production to the income of smallholder forest farmers is US$42.24 per year (4.3%) and from non-timber forest production it is US$166.51 per year (16.8%) (Pancasari 2016). Based on Law No. 32 of 2009, forest sustainability and optimal environmental conditions can be attained if at least 30% of the total land area is covered by forests. In the Special Region of Yogyakarta, private forests constitute 70% of the total land area, contributing significantly to achieve the country's 30% forest coverage target. This indicates that the environmental benefits derived from forest ecosystems in the mainland area of Yogyakarta Province are largely due to the presence of private forests (Broto et al. 2017). Timber with a harvest cycle of 20 to 30 years serves as long-term savings for smallholder farmers in Gunungkidul (Roshetko et al. 2013b). Teak accounts for 56% of the trees in these systems and other timber species account for an additional 21% (Roshetko et al. 2013a). Local plantings of teak are usually slow growing, with smallholder teak systems described as overstocked, slow growing, and of suboptimal quality and production (Roshetko et al. 2009). Economically, private forests have the function of increasing the income of smallholder farmers and the timber industry, and providing employment opportunities (Broto et al. 2017). In 2013, the 3,464 wood industries in Gunungkidul employed 14,413 workers, with a production value of more than US$320,000 per year (Listyanto and Yuwono 2017).

Community forest management for timber production requires short-rotation and long-rotation companion species to fulfill the demands of the timber industry, improve farmers' welfare and sustain the environment. Proactive silvicultural management, particularly thinning, will enhance system productivity, value and financial returns (Roshetko et al. 2013; Kanninen 2004). Farmers and communities remain reluctant to thin their teak systems because they consider thinning a loss of future income (Perdana et al. 2012; Sabastian et al. 2017). It would be beneficial to have short-rotation timber crops as companion species in teak systems, which would enable early thinning to yield commercial products (Roshetko et al. 2004, Roshetko et al. 2013c).

Possible fast-growing short-rotation companion species include *Falcataria moluccana* (syn. *Paraserianthes falcataria*), *Neolamarckia cadamba* (syn. *Anthocephalus cadamba*), *Acacia mangium* and *Gmelina arborea* (gmelina). The rotation of *F. moluccana* is 6 years (Kallio et al. 2011; Riyanto and Pamungkas 2010). Similarly, the rotation of *N. cadamba* is 5 to 6 years (Indrajaya and Siarudin 2013; Krisnawati et al. 2011a). The optimum rotation of *A. mangium* and *G. arborea* is 8 years (Indrajaya and Siarudin 2013; Indrajaya and Astana 2017; Mindawati and Pratiwi 2008; Permana 2006). The natural distribution of 3 of these species is predominantly in Southeast Asia – *F. moluccana* and *N. cadamba* are native to Indonesia (Krisnawati et al. 2011a; Krisnawati et al. 2011d), and *A. mangium* is native to Papua New Guinea and Australia (Kurnia et al. 2014; Krisnawati et al. 2011b) but is now common in Indonesia. *Gmelina arborea*, native to South Asia, is a priority species for the rehabilitation of critical lands and the development of timber plantations (Hadijah 2013). These 4 fast-growing species may have sufficient adaptability to have potential as companion species for community forest conditions in Gunungkidul's dry-rocky soils.

Practising silviculture remains uncommon, ensuring continued low productivity and quality (Sabastian et al. 2017; Sastrasupadi 2000; Enters 2000). Smallholder farmers do not recognise the importance of recommended silviculture management (Wiyono et al. 2018), resulting in few smallholders practising silvicultural management (Roshetko et al. 2013; Sabastian et al. 2017). The ideal teak silvicultural practices are the use of superior seeds, more intensive maintenance, pruning and thinning trees, and eradication of pests and diseases (Sabastian, Kanowski and Roshetko 2014; Soekotjo 2004; Wiyono et al. 2018).

In Gunungkidul, weeding and fertilising of timber trees are only done when intercropping with annual crops (73% of farmers) (Roshetko et al. 2009). Teak monocultures are generally not fertilised (Enters 2000). Most farmers (65%) prune their teak trees, but only to harvest fuelwood (Roshetko et al. 2013a, 2009; Wiyono et al. 2018). Farmers generally consider thinning an unprofitable practice (Wiyono et al. 2018). Most teak systems in Gunungkidul (57%) are managed without thinning to increase growth and stand quality.

Figure 10-10: *Gmelina arborea* (6 months old)
Credit: Dewi Maharani

The normal local practice is to thin by harvesting the biggest timber trees and leaving the smaller trees (Roshetko et al. 2013b; Sabastian et al. 2017). Without thinning, with high density and low light intensity, teak trees do not achieve their growth potential (Rohadi et al. 2010). Most farmers do not develop a harvest plan according to the teak growth cycle. They harvest trees when they have an urgent need for cash (Roshetko et al. 2013a; Wiyono et al. 2018). The traditional harvesting system is called *tebang butuh* or 'felling for need' (Roshetko et al. 2013a). In summary, smallholders harvest their trees when in need, rather than to achieve optimal financial returns (Kallio et al. 2011).

Fast-growing timber species could be interplanted with teak by row – one row of teak, one row of fast-growing timber species – to accommodate farmers' needs for short-term income and their belief that thinning teak is unprofitable. Mixed plantations of teak and short-rotation timber species would make the first thinning a commercial operation, enhancing the growth of the residual teak stand and providing income for the tree grower (Bappeda Gunungkidul 2012). In the teak monoculture, thinning is recommended when trees are 4 to 6 years old to reduce tree density (40%–60% thinning intensity) (Roshetko et al. 2013b, Kanninen et al. 2004; Bappeda Gunungkidul 2012; Rohadi et al. 2010; Pérez and Kanninen 2005). In the mixed-row system, a 50% thinning could be conducted, harvesting all the fast-growing timber species. Perum Perhutani, the state-owned forest enterprise, has trialled mixed plantations of 75% teak with 25% of *Acacia mangium*, *Eucalyptus pellita* and *Melia azedarach*. Of the 3 intercropped short-rotation timber species, only *M. azedarach* failed (Seo et al. 2015).

Intensive silviculture of mixed teak plantations can provide several benefits (Vigulu et al. 2019), including the following:

- The fast-growing species provide medium-term or short-term income.
- Pruning improves stem quality (and provides fuelwood).
- Thinning improves the growth rate and quality of the residual stand.

Adopting these silvicultural practices would enable smallholder teak farmers to produce bigger, better-quality teak faster than with current practices. Intensive thinnings (more than 50%) have a positive effect on the stem form, inducing the development of trees with the desired combination of diameter at breast height (DBH) and total height (Pérez and Kanninen 2005). See Table 10-4 on price changes relative to diameter.

Table 10-4: Sample price changes relative to diameter for smallholders' teak in Gunungkidul between 2008 and 2018

Age (year)	Diameter at breast height (cm)	Price accepted by producer (US$ per standing tree)	Log volume after processing by traders (m^3)	Log price collected by trader (US$)
10	12–18	3–6	0.045–0.189	3–25
15	13–31	5–30	0.060–0.515	6–123
20	21–45	10–265	0.307–1.061	57–284
25	29–49	20–296	0.320–1.321	54–329

Clonal teak grows faster than common teak in the state forest in Java, but teak forest smallholders in Gunungkidul cannot afford these superior clone seeds, which are relatively expensive. In clonal teak monocultures on Java, with an initial spacing of 6 m × 2 m, 50% thinning in year 4 yielded the best growth increment and standing stock 3 years after thinning (compared to 25% thinning and no thinning) (Bappeda Gunungkidul 2012).

General recommendations for a teak system with a 30-year cycle are 5 thinnings with 20%–50% intensity at the age of 4, 8, 12, 18 and 24 years (Rohadi et al. 2010). Thinning and pruning promoted positive DBH growth and an increase in the economic value of the residual stand, with no negative effects on the wood properties of the stems (Rohadi et al. 2020; Pérez and Kanninen 2005). In clonal teak plantations in degraded soils, short-rotation commercial thinning could maintain growth rates and provide income for farmers (Bappeda Gunungkidul 2012). For example, sengon (*F. moluccana*) plantation forest with a short rotation (8 years) produces a BCR of 1.8:1 and an internal rate of return of 49.07% (Ethika et al. 2014). *Gmelina arborea* (known as jati putih) is also a short-rotation timber species that could be developed in Indonesia (Roshetko, Mulawarman and Purnomosidhi 2004) and could be mixed with teak for commercial thinning (Sudomo et al. 2021). Previously, farmers were reluctant to thin teak because the thinning wood was not selling well, but with a mixture of short-rotation timber species commercial thinning would increase their incomes (Sudomo et al. 2021).

A mixed-row system of teak and short-rotation timber species has an added benefit to farmers over monocultures. In community forestry, such smallholder teak systems enable the first thinning at 5 to 8 years to become a commercial operation. The increasing demand for wood and its increasingly limited availability have boosted the market for short-rotation timber. The use of short-rotation timber is not only for carpentry, but also for particle board, containers and laminated wood. Commercial thinning of short-rotation timber species will provide more immediate income to farmers, while enhancing the productivity of the remaining teak stand.

Gmelina had the highest survival rate (87.3%) and the best growth performance (17.64 m^3/ha) in Semin sub-district, Gunungkidul. Jabon (*Neolamarckia cadamba*) grew rapidly (7.86 m^3/ha) but had a low survival rate (40.6%) due to its drought vulnerability in the dry-rocky soil of the study site. A literature review indicated that survival of *N. cadamba* can be improved through fertilisation and biochar treatment. While *Acacia mangium* survived well (78.2%), it had a low growth rate (3.01 m^3/ha). Advanced evaluation of its growth rate in subsequent years is required to ensure its feasibility as a teak companion in mixed planting. Sengon (*Falcataria moluccana*) had the lowest survival rate (18%) and growth rate (1.38 m^3/ha) at the study site, so it is not recommended for mixed plantations with teak. Based on the characteristics of growth performance at the study site, *G. arborea* and *N. cadamba*, which are similar to teak, are recommended as teak companions in mixed planting. These short-rotation timber species mixed with teak can be harvested at 5 to 8 years of age during the first commercial thinning.

Intercropping short-rotation timber species and agriculture crops will encourage farmers to adopt silvicultural management and a more commercial approach towards their teak systems. Therefore, silvicultural treatment to allow fast-growing timber species to survive drought (defined as a 5-month period without a day of rain) at the beginning of growth is very important. The changing dynamics of dry months and wet months that may occur in the future needs to be anticipated by selecting drought-resistant species (genetic material). In our study, during the first year after planting there was an increase in dry months (6 months and a decrease in rainfall, only 1,837 mm/year) compared to previous years (BPS 2020). Even in 2018, the site had a 5-month period without a day of rain (BPS 2020). Short-term returns and a more diverse income base will also enable farmers to cultivate their land more intensively.

Ecologically, trees reduce erosion risks due to their extensive and strong root systems binding with rocks in the forest ground, especially in the Gunungkidul area. Teak and short-rotation timber species in the mixed pattern offer farmers a real market advantage, provided that the recommended silvicultural management is applied. Intensive silviculture is essential to enhance the productivity of teak systems in the drought-vulnerable dry-rocky soils in Gunungkidul.

Teak-based agroforestry as a food production system – Gunungkidul, central Java

Agroforestry systems in Gunungkidul district's community forest and private forests have been adopted to lift food production to match the needs of the growing population, and increase household income by adding more agricultural marketable products. Private forests and agroforestry have been practised for generations as a form of adaptation to marginal and dry land conditions to meet the subsistence needs of the community (Oktalina and Hartono 2015). Smallholder farmers applied the intercropping system in Gunungkidul on their less-than 3-year-old teak stand with shade-intolerant species such as cassava, peanuts, upland rice, soybean and long beans (Roshetko et al. 2013b). However, the diversification of food crops requires more effective land use. In Gunungkidul, high-density teak plantations have dominated many private forests, with the area under the tree crown receiving such low light intensity that only shade-resistant plants can survive. Tubers are among the potential species to be developed under forest stands in an agroforestry pattern (Maryanto 2013; Sibuea, Kardhinata, and Ilyas 2014) and a way of diversifying carbohydrate-producing foods beyond rice (A Wahyono et al. 2017; al Hamzah 2011).

Figure 10-11: Arrowroot tubers are pounded to make arrowroot flour in the traditional way.
Credit: Aris Sudomo

Box 10-2: Making more profit from teak

National and international demand for teak timber exceeds the sustainable yield from natural forests and plantations. High demand creates opportunities for enterprising farmers. Timber is not the only teak product that generates income for smallholders – collecting and producing teak germplasm is also profitable.

Farmers in Wonogiri, Central Java, and Ponorogo, East Java, earn between US$3.30 and US$4.10 a day by supplying teak seed to seed dealers and companies. Farmer seed collectors estimate that they earn between US$32 and US$94 a year by collecting and processing tree seeds of all species, which equalled between 33% and 66% of household cash incomes during the 3-month tree-seed season. In Java, teak accounts for 20% of all tree seeds collected and sold. About 22,500 farmers are involved in the tree-seed sector. In Lampung Province in Sumatera, 24% of farmer nurseries and 100% of farmer timber-tree nurseries produce teak trees for sale to government, commercial and farmer customers.

Both farmers and traders are motivated by higher prices for higher quality timber. However, farmers' incentives to produce higher quality timber are constrained by poor market links and lack of price incentive. Those links are restricted by their limited access to market information, a weak negotiating position and the small quantities of undersized trees of uncertain quality that they produce. It is suggested that by introducing smallholders to the log-grading and pricing systems used by the timber industry they will become more informed about marketing. Training sessions led by industry experts could improve the knowledge of smallholders, and the local traders to whom they sell their logs.

These interactions could be expanded to become farmer–industry partnerships where farmers produce trees to meet market specifications. The development of a valuation system for on-farm standing trees could reduce the risk for both smallholders and traders. Improving their confidence in the price to be received could be the incentive smallholders need to produce better quality timber.

Due to the high proportion of rock on the soil surface, farming on the rocky dry land has proven challenging and limited cultivation has taken place. Furthermore, the competition between growing annual and perennial plants is a potential obstacle for smallholders adopting agroforestry in private forests for food crop production (Rohandi 2018).

Local food commodities can play an important role in achieving food sustainability (Samadi and Mallipu 2021). In forest margin communities, diversification of staple food production to local commodities has enhanced income security and, thereby, food security (Van Noordwijk et al. 2018). Tubers such as arrowroot (*Maranta arundinacea* L.), canna (*Canna edulis* Kerr.) and yam (*Dioscorea esculenta*) hold potential as food ingredients, including for the flour industry and human health nutraceutical market (Chandrasekara and Kumar 2016). Arrowroot, canna and yama can act as alternative staple foods to rice because of their high carbohydrate value. Small and medium industries in Gunungkidul use these tubers as raw material for making flour which has the potential to replace wheat flour.

Arrowroot has high yield potential, high-quality starch and multiple benefits for the treatment of autism, diabetes and digestive disorders (Deswina and Priadi 2019). Arrowroot starch is used in both the food and non-food industries, alongside corn, potato, cassava and wheat flour (Yazid et al. 2018). Canna rhizome has potential as a functional ingredient for food and pharmaceutical industries. Canna can be used as an alternative food source and as the basic ingredient of instant noodles and biscuits (Lai et al. 1980). Yam, apart from being a carbohydrate source, can be used for various industrial and medicinal purposes (Nugraheni et al. 2020; Harijono et al. 2013). Yam flour can be mixed into popular food products, such as cookies (Prameswari and Estiasih 2013). With a carbohydrate content (between 22.5% and 31.3%) similar to rice, yam could substitute for rice as a staple food source (Sabda et al. 2019) and can be consumed after simple preparation.

Transforming *kitren* (monoculture woodlots) into intercropped systems will optimise land use. In Gunungkidul, many farmers have intercropped their teak systems (mainly in *tegalan*) with agricultural crops – cassava (26.6% of intercropped parcels), peanuts (23.8%), upland rice (18.0%), soybeans (8.1%) and long beans (2.9%) (Roshetko et al. 2013c). Most agroforestry patterns that have been successfully established were food crops in *tegalan* and home garden systems, with relatively high intensity light). The trees along the border of the pattern act as a fence that surrounds the food plants, creating potential for various sources of sunlight, water and nutrients in the agroforestry system (Suryanto et al. 2017).

Reducing tree density (thinning) is the first requirement to make space for intercropping. However, farmers are reluctant to thin the teak, resulting in low intensity light and limited space in the understorey (Sabastian et al. 2019). Therefore, in private forests (*kitren*) they will need to select low-light-resistant tuber species under teak shade (more than 5-year-old teak) for food productivity and optimisation of understorey space. See Table 10-5 for further information.

Table 10-5: Tuber production (tonne/ha) when intercropped with teak

Position	Species of tuber plant (tonne/ha)		
	Arrowroot	Canna	Yam
Open area	26.64±1.61	1.06±0.25	23.49±3.45
Beneath 5-year-old teak	6.21±1.91	1.06±0.70	5.65±1.76
Beneath 7-year-old teak	2.94±0.56	1.58±0.51	3.06±0.39

Source: Maharani et al. (2022)

Optimising land under food crops is expected to increase food production (FAO 2019). In general, many types of food crops are cultivated in open areas, but some tuber species (arrowroot, canna and yam) can grow under tree shade of between 30% and 70% (Chandrasekara and Kumar 2016; Deswina and Priadi 2019; Yazid et al. 2018; Lai et al. 1980; Nugraheni et al. 2020). These 3 types of tubers grow in many community home gardens in Gunungkidul. They are usually planted in community agroforestry systems under the trees (Harijono et al. 2013). These tropical and perennial tuberous plants have been underutilised despite their potential as an alternative food source (Prameswari and Estiasih 2013; Sabda et al. 2019). Arrowroot is adapted to low light (FAO 2019; Oktafani et al. 2017). It survives under poor light and on infertile land, characteristics that are required for a shaded place (Deswina and Priadi 2019). Yam grows at 60% to 70% light intensity (Miller 2003), while canna is drought-resistant and suitable for cultivation under shade with low light intensity (Azis 2013). The highest production of canna tubers was in 50% shade (Utami and Diyono 2016).

The ideal management of annual and perennial crops in an agroforestry system varies by biophysical, economic and social conditions (Wu et al. 2020). In an experiment to increase land productivity under 5-year-old and 7-year-old community forest teak stands in Gunungkidul, 3 shade-resistant tuber species – canna, yam and arrowroot – were intercropped with the teak. This experiment produced 3 variations of relative light intensity (RLI), namely 48% (7-year-old teak), 38% (5-year-old teak) and 100% (open field / tuber monoculture). While the results showed different tuber growth rates and productivity rates, the starch content of the 3 types of tubers was not significantly affected by the RLI. This indicates that the quality of tuber production under different treatments was similar. The production of canna tubers was most consistent, regardless of the RLI. Canna is recommended as the most shade-resistant understorey crop for teak agroforestry with RLI values of 38% and 45%. At both light intensities, production did not decrease compared to the open area. In previous studies, canna remained productive at 50% light intensity. The tuber weight of arrowroot and yam decreased as the RLI decreased.

There are some specific factors, however, that influence tuber productivity – namely, light intensity, soil conditions, climate, cultivation methods (agriculture intensification and teak silviculture) and cultivar varieties. Our project provided a useful initial evaluation of the productivity of 3 shade-tolerant tubers growing under the shade of 5-year-old teak (45% of RLI), 7-year-old teak (38.76% of RLI), and with unthinned and unpruned teak. Planting 3 shade-tolerant tuber species as understorey to optimise the land use of the 5-year-old teak stands in dry land of private forests holds potential for generating annual income and producing alternative food sources for rural farming communities.

The contribution of agroforestry to smallholder livelihoods was demonstrably greater than that of a monoculture (land equivalent ratio (LER)[18] greater than 1), especially for teak under 5 years old (Table 10-6). This shows that a combination of teak and tuber plants can be recommended. Research in the future could measure the effectiveness of thinning and pruning on teak at several spacings, and to what degree crop maintenance intensification increases the productivity of food-producing tubers in a smallholder teak system.

Table 10-6: Land equivalent ratio of intercropping teak and tubers

Treatment	Land equivalent ratio		
	Arrowroot + Teak	Canna + Teak	Yam + Teak
5-year-old teak	1.65	2.65	1.27
7-year-old teak	0.69	2.01	0.73

Source: Maharani et al. (2022)

18 LER is a formula for calculating land productivity in agroforestry patterns compared to monoculture patterns. A LER value of more than 1 indicates that the agroforestry planting pattern can increase land productivity and is profitable compared to the monoculture pattern because it consists of the accumulative productivity of the constituent plants in the agroforestry system.

Summary of key findings

Many farmers in Indonesia have either adopted high-value timber-based agroforestry systems or are involved in the collection and sale of non-timber products, often from remnant forest areas. While the agroforestry systems provide many benefits to the farmers, such as the ability to generate cash when they have large expenses, the trees take several years to reach a saleable size and these systems do not provide the regular sources of income that farmers need.

By focusing on developing agroforestry in smallholder farming areas in Indonesia's poorest provinces, in Nusa Tenggara islands, and in smallholder teak production areas on its most densely populated island (Java), government will create opportunities for these smallholder communities and several industry sectors to:

- alleviate poverty through integrated timber and NTFP management
- develop successful agribusiness at the micro scale and small scale
- link timber and NTFP use with community-based forestry management and micro-scale and small-scale enterprise development.

Community forests have a very important role for the people of western Nusa Tenggara. Timber production, as one of the goals in community forest management, continues to increase in line with the increasing public interest in implementing community forests. In addition to their economic function as a source of income for the community, community forests have complex ecological functions, such as increasing land cover, storing carbon, reducing erosion and surface run-off, and improving soil fertility.

Community forest management combined with agroforestry patterns has become the community's choice because it is easy to implement in the field. Community forest management with agroforestry patterns in western Nusa Tenggara has many forms according to local environmental conditions and the considerations of each landowner. Community forest management is expected to support improvements in environmental quality as well as community economy.

Some lessons to increase the productivity of community forests in western Nusa Tenggara:

- Plant species should be selected for their biophysical, social and economic suitability.
- Management should be intensive, both fertilising trees and eradicating weeds, fungi and diseases that could disrupt plant life.
- Farmers need to be introduced to ways of increasing the economic value of products from agroforestry plots, such as fruit and honey.
- Offering farmers market assurance is important in supporting the successful development of community forest productivity. The formation of cooperatives or other forms of small-scale businesses can be an effective way to facilitate marketing of agroforestry products.

In the case of Gunungkidul, using agroforestry in home gardens and dry fields is a way to meet the food needs of rural communities. Growing local tubers (yam, canna and arrowroot) as food commodities in an agroforestry pattern has the potential to meet future community food needs. Agricultural commodities offer short-term yields, short-rotation timber species offer medium-term yields, and teak offer long-term yields. Private forest as a form of cultivation on marginal land is proven to contribute positively to the environment and to meeting community needs (at least in a subsistence manner). Setting up a timber business requires collective action from smallholder farmers to overcome their limited ownership of land.

References

Affandi O, Zaitunah A and Batubara R (2017) ‘Potential economic and development prospects of non-timber forest products in community agroforestry land around Sibolangit Tourism Park’, *Forest and Society***,** 1(1):68–77.

Ahmad AG, Zaitunah A and Tambusai HK (2019) ‘Evaluation of plant species suitability for lowland forest landscape restoration in Lepan watersheds, Langkat District, North Sumatra, Indonesia’, *Biodiversitas***,** 20(10):2903–2909.

al Hamzah Z (2011) *Mandiri pangan sejahterakan rakyat: profesor hutan ke rimba politik* [biography of Suhardi], K-MAG Book, Jakarta.

Armas Dassir M and Millang S (2020), ‘Peranan berbagai pola agroforestri terhadap tingkat resiliensi petani di Sub DAS Minraleng Hulu’, *Jurnal Hutan dan Masyarakat*, 12(2):120-135.

Azis SN (2013) ’Pengaruh Naungan Sengon (*Falcataria moluccana* L.) Dan Pemupukan Terhadap Pertumbuhan Ganyong Putih (*Canna edulis* Ker.)’ [unpublished bachelor’s thesis], Institut Pertanian Bogor, Bogor, Indonesia.

Balai Kesatuan dan Pengelolaan Hutan Yogyakarta (2014) *Rencana pengelolaan jangka panjang kesatuan pengelolaan hutan produksi*, (13):1–212, Balai Kesatuan dan Pengelolaan Hutan Yogyakarta, Yogyakarta, Indonesia.

Bappeda Gunungkidul (2012) *Profil Daerah Kabupaten Gunungkidul 2012*, Bappeda Gunungkidul, Yogyakarta, Indonesia.

BPS (Badan Pusat Statistik) (2019) *Kabupaten Gunungkidul Dalam Angka 2019*, 34030.1902. ed, BPS Kabupaten Gunungkidul, Yogyakarta, Indonesia.

——(2020) *Kabupaten Gunungkidul Dalam Angka 2020*, 34030.2003. ed, BPS Gunungkidul, Yogyakarta, Indonesia.

BPS Kabupaten Sumbawa (2019) *Kecamatan Batulanteh Dalam Angka 2019*, BPS Kabupaten Sumbawa, Sumbawa Besar, Indonesia.

Broto BW, Muhammad T and Purnomo S (2017) ’Peran Pemerintah Kabupaten Gunungkidul Dalam Pengembangan Hutan Rakyat’, in Maryudi A and Nawir AA (eds) *Hutan Rakyat Di Persimpangan*, UGM Press, Yogyakarta.

Chandrasekara A and Kumar TJ (2016) ‘Roots and tuber crops as functional foods: a review on phytochemical constituents and their potential health benefits’, *International Journal of Food Science*, 2016(3631647).

Deswina P and Priadi D (2019) ‘Development of arrowroot (*Maranta arundinacea* L.) as functional food based of local resource’, in *Proceedings of the 6th International Symposium of Innovative Bioproduction Indonesia on Biotechnology and Bioengineering*, Tangerang, Indonesia, 23–24 October 2019.

Diniyati D and Achmad B (2015) ‘Kontribusi pendapatan Hasil Hutan Bukan kayu pada usaha hutan rakyat pola agroforestri di Kabupaten Ciamis’, *Jurnal Ilmu Kehutanan*, 9(1):23–31.

Enters T (2000) ‘Site, technology and productivity of teak plantations in Southeast Asia’, *Unasylva*, 51(201):55–61.

Ethika D, Ris HP, Senawi S and Masyhuri M (2014) ‘Kontribusi usaha hutan rakyat di bagian hulu sub das Logawa Kabupaten Banyumas (Kajian kelayakan usaha kayu sengon di Kecamatan Kedungbanteng)’, *Agrin*, 18(2).

FAO (Food and Agriculture Organization of the United Nations) (2019) *OECD-FAO Agricultural Outlook 2019–2028*; FAO, Rome, Italy, ISBN 92-5-131374-1.

Hadijah MH (2013) ‘Pengaruh perbedaan suhu awal air rendaman dan lama perendaman terhadap perkecambahan benih gmelina (*Gmelina arborea* Roxb.). J. Ilm’, *Agribisnis Dan Perikan*, 6:64–72.

Hamdani KK and Susanto H (2020) ’Pengembangan varietas tahan naungan untuk mendukung peningkatan produksi tanaman pangan’, *Jurnal Planta Simbiosa*, 2(1):22–36.

Harijono H, Estiasih T, Saputri DS and Kusnadi J (2013) ‘Effect of blanching on properties of water yam (*Dioscorea alata*) flour’, *Advance Journal of Food Science and Technology*, 5:1342–1350.

Hernawan E, Rostiwati M, Lastini T, Sofiatin, Dwiartama A and Rahman H (2020) ‘Agroforestry as a model of sustainable land use of small-scale private forest: a case study in Sumedang, West Java, Indonesia’, *International Journal of Business Continuity and Risk Management*, 10(2,3).

Indrajaya Y and Astana S (2016) ‘Daur optimal gmelina pada proyek karbon dan aforestasi’, *Jurnal Sosek Kehutan*, 7:145–154.

Indrajaya Y and Siarudin M (2013) ’Daur finansial hutan rakyat jabon di Kecamatan Pakenjeng, Kabupaten Garut, Jawa Barat’, *Jurnal Penelitian Hutan Tanam*, 10:201–211.

Iskandar J, Iskandar BS and Partasasmita R (2017) ’Introduction of *Paraserianthes falcataria* in the traditional agroforestry “huma” in Karangwangi Village, Cianjur, West Java, Indonesia’, *Biodiversitas*, 18(1):295–303.

Kallio M, Kanninen M and Rohadi D (2011) 'Farmers' tree planting activity in Indonesia—case studies in the provinces of Central Java, Riau, and South Kalimantan', *Forests, Trees and Livelihoods*, 20:191–209.

Kanninen M, Pérez D, Montero M and Víquez E (2004) 'Intensity and timing of the first thinning of *Tectona grandis* plantations in Costa Rica: results of a thinning trial', *Forest Ecology and Management*, 203:89–99.

Krisnawati H, Kallio M and Kanninen M (2011a) Antohocephalus cadamba Miq.: *ekologi, silvikultur, dan produktivitas*, CIFOR, Bogor, Indonesia, ISBN: 978-602-8693-38-7.

——(2011b) Acacia mangium *Willd.: ekologi, silvikultur dan produktivitas*; CIFOR, Bogor, Indonesia.

——(2011c) Aleurites moluccana *(L.) Willd.: ecology, silviculture and productivity*, CIFOR, Bogor, Indonesia.

Krisnawati H, Varis E, Kallio MH and Kanninen M (2011d) Paraserianthes falcataria *(L.) Nielsen: ecology, silviculture and productivity*, CIFOR: Bogor, Indonesia.

Kurnia N, Jumadi O and Hiola SF (2014) *Atlas tumbuhan Sulawesi Selatan*, University of Makassar, South Sulawesi Province, Indonesia.

Kurniasih H, Ford RM, Keenan RJ and King B (2021) 'The evolution of community forestry through the growth of interlinked community institutions in Java, Indonesia', *World Development*, 139:105319.

Kurniawan A, Hidayat JW and Amirudin (2020) 'Challenges of private forests management in Cluwak sub-district, Pati Regency, Indonesia', *E3S Web of Conferences*, 202:06013, doi:10.1051/e3sconf/202020206013.

Lai K, Tsai Y and Wang T (1980) 'Studies on the edible canna in Taiwan: botanical characteristics and economical use of edible canna', Journal of the Agricultural Association of China, 111:1–14.

Listyanto T and Teguh Y (2017) 'Analisis daya saing industri kecil dan menengah berbasis bahan baku hutan rakyat dalam menghadapi era sertifikasi: studi kasus di Yogyakarta dan Jepara', in Maryudi A and Nawir AA (eds) *Hutan Rakyat Di Persimpangan*, UGM Press, Yogyakarta, Indonesia.

Maharani D, Sudomo A, Swestiani D, Murniati, Sabastian GE, Roshetko JM, Fambayun RA (2022) 'Intercropping tuber crops with teak in Gunungkidul Regency, Yogyakarta, Indonesia', *Agronomy*, 12(449), doi:10.3390/agronomy12020449.

Maryanto I (2013) *Bioresources untuk pembangunan ekonomi hijau*, Lembaga Ilmu Pengetahuan Indonesia, Jakarta.

Mataram (29 April 2020) 'Dutch buyer requests 40 tons of organic ginger a month', *SuaraNTB*, accessed 3 November 2023. https://www.suarantb.com/2020/04/29/buyer-belanda-minta-40-ton-jahe-organik-sebulan/

Miller JH (2003) *Nonnative invasive plants of southern forests: a field guide to identification and control*, GTR-SRS-62, U.S. Department of Agriculture, Forest Service, Asheville, NC, USA.

Mindawati N and Pratiwi P (2008) 'Kajian Penetapan Daur Optimal Hutan Tanaman *Acacia mangium* Ditinjau Dari Kesuburan Tanah', *Jurnal Penelitian Hutan Tanam*, 5:109–118.

Murniati (2016) 'Teknologi agroforestri komplek-permanen berbasis pangan untuk mendukung ketahanan pangan nasional', *Prosiding Semnas Agroforestri : Inovasi Agrofo-restri Mendukung Kemandirian Bangsa*, pp. 157–164.

—— (2020) *Penguatan teknologi agroforestri selama daur dalam pengelolaan hutan berbasis masyarakat* [Naskah orasi pengukuhan profesor riset bidang teknologi agroforestri, 89 Hal], Kementerian Lingkungan Hidup dan Kehutanan, Jakarta.

Nandini R (2017) *Model pengembangan kehutanan masyarakat berkelanjutan berbasis Daerah Aliran Sungai di DAS Babak, Pulau Lombok* [disertasi], Universitas Gadjah Mada, Yogyakarta.

Nandini R, Susila IWW and Hidayatullah M (2021) *Peningkatan produktivitas rakyat melalui pengembangan agroforestri di Nusa Tenggara Barat*, Nas Media Utama, Yogyakarta.

Nawir AA, Amirah Y and Purnomo S (2017) 'Menuju pengelolaan hutan rakyat yang berorientasi bisnis unutk menunjang penghidupan yang berkesinambungan', in Maryudi A and Nawir AA (eds) *Hutan Rakyat Di Persimpangan*, UGM Press, Yogyakarta, Indonesia.

Nugraheni NF, Karyadi JNW, Tarwaca SN, Indrasari YP, Albyan R, Setiyadi I and Ayuni D (2020) 'Effect of various drying methods on the physical characteristics of purple yam powder', *Proceedings of the International Conference in Agricultural Technology, Engineering, and Environmental Science*, Banda Aceh, Indonesia, 21 September 2020.

Oktafani MB, Supriyono, Budiastuti MS and Purnomo D (2017) 'Performance of arrowroot (*Marantha arundinacea*) in various light intensities', *Proceedings of the 4th International Conference on Sustainable Agriculture and Environment (4th ICSAE)*, Surakarta, Indonesia, 10–12 August 2017.

Oktalina SN and Slamet H (2015) 'Strategi petani hutan rakyat dan kontribusinya terhadap penghidupan di Kabupaten Gunungkidul', *Kawistara* 5(3).

Pancasari AG (2016) 'Kontribusi hutan rakyat terhadap pendapatan rumah tangga petani di desa Pilangrejo Kecamatan Nglipar, Kabupaten Gunungkidul' (not published).

Paut R, Sabatier R and Tchamitchian M (2018) 'Horticultural agroforestry systems: a modelling framework to combine diversification and association effect' [conference paper], *4th European Agroforestry Conference: agroforestry as sustainable land use*, Nijmegen, The Netherlands, pp. 437–441.

Perdana A, Roshetko JM and Kurniawan I (2012) 'Forces of competition: smallholding teak producers in Indonesia', *International Forestry Review*, 14:238–248.

Pérez D and Kanninen M (2005) 'Effect of thinning on stem form and wood characteristics of teak (*Tectona grandis*) in a humid tropical site in Costa Rica', *Silva Fennica*, 39:217–225.

Permana D (2006) 'Penentuan daur optimum kelas perusahaan *Acacia mangium* Willd. di kesatuan pemangkuan hutan Bogor Perum Perhutani Unit III Jawa Barat dan Banten' [doctoral thesis], IPB University, Bogor, Indonesia.

Prameswari RD and Estiasih T (2013) 'Pemanfaatan tepung gembili (*Dioscorea esculenta* L.) dalam pembuatan cookies', *Jurnal Pangan dan Agroindustri*, 1:115–128.

Riyanto HD and Pamungkas B (2010) 'Model pertumbuhan tegakan hutan tanaman sengon untuk pengelolaan hutan', *Tekno Hutan Tanam*, 3:113–120.

Rohandi A (2018) 'Productivity and quality of three varieties of ginger on many light intensity levels under stand of pine', Jurnal Agroforestri Indonesia, 1:1–13.

Roshetko JM and Manurung GE (2009) 'Smallholder teak production systems in Gunungkidul, Indonesia', *Proceedings of the 2nd World Congress of Agroforestry: The future of global land use*, Nairobi, Kenya, 24–28 August 2009.

Roshetko JM, Mulawarman and Purnomosidhi P (2004) '*Gmelina arborea* - a viable species for smallholder tree farming in Indonesia?', *New Forests*, 28: 207–215.

Roshetko JM, Rohadi D, Perdana A, Sabastian G, Nuryartono N, Pramono AA, Widyani N, Manalu P, Fauzi MA, Sumardamto, Kusumowardhani N (2013a) 'Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation', *Forests, Trees and Livelihoods*, 22(4):241–256, doi:10.1080/14728028.2013.855150.

Roshetko JM, Rohadi D, Perdana A, Sabastian G, Pramono AA, Nuryartono N, Pramono AA, Widyani N, Manalu P, Fauzi MA, Sumardamto P (2013b) 'Teak systems' contribution to rural development in Indonesia', *World Teak Conference 2013*, 25–30 March 2013, pp. 24–27.

Roshetko JM, Rohadi D, Perdana A and Sabastian G (2013c) 'Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation', *Forests, Trees and Livelihoods*, 22(4):241–256, doi:10.1080/14728028.2013.855150.

Sabastian G, Kanowski P and Roshetko JM (2014) 'Household and farm attributes affecting adoption of smallholder timber management practices by tree growers in Gunungkidul Region, Indonesia', *Agroforestry Systems*, 88(2):257–268, doi:10.1007/s10457-014-9673-x.

Sabastian GE, Yumn A, Roshetko JM, Manalu P, Martini E and Perdana A (2017) 'Adoption of silvicultural practices in smallholder timber and NTFPs production systems in Indonesia', *Agroforestry Systems*, 93:607–620.

Sabda M, Wulanningtyas HS, Ondikeleuw M and Baliadi Y (2019) 'Karakterisasi potensi gembili (*Dioscorea esculenta* L.) lokal asal papua sebagai alternatif bahan pangan pokok', *Buletin Plasma Nutfah*, 25:25–32.

Sahidu A, Muktasam, Nurjannah S and Hayati (2018) 'Analisis rantai nilai kemiri dan strategi pemberdayaan petani: studi kasus di Desa Batudulang Kecamatan Batulanteh-Kabupaten Sumbawa', *Jurnal Agrimansion*, 19(1):1–14.

Samadhi N and Mallipu A (16 October 2021) 'A reviving local food achieving sustainable food system', *The Jakarta Post*.

Sastrasupadi A (2000) *Rancangan percobaan praktis bidang pertanian*, Kanisius, Yogyakarta, Indonesia.

Seo J-W, Kim H, Chun J-H, Mansur I and Lee C-B (2015) 'Silvicultural practice and growth of the jabon tree(*Anthocephalus cadamba* Miq.) in community forests of West Java, Indonesia', Journal of Agriculture and Life Sciences, 49(4):81–93.

Setiawan H, Barus B and Suwardi (2014) 'Analisis potensi pengembangan hutan rakyat di Kabupaten Lombok Tengah', *Majalah Ilmiah Globe*, 16 (1):69–76.

Sibuea SM, Kardhinata EH and Ilyas S (2014) 'Identifikasi dan inventarisasi jenis tanaman umbi-umbian yang berpotensi sebagai sumber karbohidrat alternatif di Kabupaten Serdang Bedagai', *Jurnal Online Agroekoteknologi*, 2(4):1408–1418.

Siddik M, Zaini A, Budastra IK and Zubair M (2018) 'Pengembangan rantai nilai komoditas kemiri sebagai upaya pengentasan kemiskinan dan pelestarian sumberdaya hutan di kawasan hutan Gunung Rinjani Lombok Utara', *Jurnal Agrimansion*, 19(2):99–112.

Soekotjo (2004) 'Silvikultur hutan tanaman: prinsip-prinsip dasar' in Hardiyanto EK and Arisman H (eds) *Pembangunan Hutan Tanaman Acacia mangium*, PT Musi Hutan Persada, Indonesia.

Sudomo A and Maharani D (2019) 'Application of plant diversity through complex agroforestry on three land use system', in Justin A. Daniels (ed) *Advances in environmental research*, Volume 73, pp. 47–75, Nova Science Publishers, New York.

Sudomo A, Maharani D, Swestiani D, Sabastian GE, Roshetko JM, Perdana A, Prameswari D and Fambayun RA (2021) 'Intercropping short rotation timber species with teak: enabling smallholder silviculture practices', *Forests*, 12(12):1761.

Suhartati T, Purwanto RH, Setyarso A and Sumardi S (2021) 'Karakteristik pengelolaan hutan rakyat dalam perspektif sistem (Studi Di Desa Semoyo Kabupaten Gunung Kidul)', *Jurnal Hutan Tropis*, 9(3):355.

Susila IWW, Manurung GES and Prameswari D (2018) 'Uji coba penanaman Rumput Ketak (*Lygodium circinnatum* Burm.F) pada hutan rakyat kemiri di Desa Batudulang, Sumbawa', *Proseding Seminar Hasil Penelitian Kanoppi: Optimalisasi pengelolaan hutan berbasis agroforestri untuk mendukung peningkatan produktiftas kayu dan HHBK serta pendapatan petani*, Pusat Penelitian dan Pengembangan Hutan, Bogor, Indonesia, pp. 29–43.

Susila IWW, Nandini R and Setyayudi A (2021) 'Pertumbuhan tanaman ketak (*Lygodium circinnatum* (Burn.F.) Swartz) dengan pemupukan pada beberapa pohon rambatan di KHDTK Rarung Lombok Tengah', *Jurnal Perbenihan Tanaman Hutan*, 9(1):1–14.

Tania R, Widjaya S and Suryani S (2019) 'Usahatani, pendapatan dan kesejahteraan petani kopi di Lampung Barat', *Jurnal Ilmu-Ilmu Agribisnis*, 7(2):149–156.

Utami NW and Diyono D (2016) 'Respon pertumbuhan dan produksi 4 varian ganyong (*Canna edulis*) terhadap intensitas naungan dan umur panen yang berbeda', *Jurnal Teknologi Lingkungan*, 12:333–343.

Utomo EWB, Widiatmaka and Rusdiana O (2021) 'Potensi lahan tersedia untuk pengembangan hutan rakyat di Kabupaten Gunungkidul, Provinsi D.I. Yogyakarta', *Journal of Natural Resources and Environmental Management*, 11(1):108–119.

Van Noordwijk M, Duguma LA, Dewi S, Leimona B, Catacutan DC, Lusiana B, Öborn I, Hairiah K and Minang PA (2018) 'SDG synergy between agriculture and forestry in the food, energy, water and income nexus: Reinventing agroforestry?', *Current Opinion in Environmental Sustainability*, 34:33–42.

Vigulu V, Blumfield T, Reverchon F, Hosseini Bai S and Xu Z (2019) 'Growth and yield of 5 years old teak and flueggea in single and mixed species forestry systems in the Solomon Islands', *New Forests*, 50:629–642.

Wahyono A, Arifianto A, Wahyono ND and Riskiawan HY (2017) 'Prospek ekonomi kebijakan pemanfaatan produktivitas lahan tidur untuk pengembangan porang dan Jamur Tiram di Jawa Timur', *Jurnal Cakrawala*, 11(2):171–180.

Wiyono W, Lestari P, Hidayat R, Oktalina SN, Utomo S, Prasetyo E, Ngadianto A, Nugroho P (2018) 'Penerapan teknik silvikultur intensif pada pengelolaan hutan rakyat di Kabupaten Gunungkidul', *Jurnal Pengabdian dan Pengembangan Masyarakat Indonesia*, 1:57–70.

Wu J, Zeng H, Zhao F, Chen C, Liu W, Yang B and Zhang W (2020) 'Recognizing the role of plant species composition in the modification of soil nutrients and water in rubber agroforestry systems', *Science of the Total Environment*, 723:138042.

Yazid NSM, Abdullah N, Muhammad N and Matias-Peralta HM (2018) 'Application of starch and starch-based products in food industry', *Journal of Science and Technology*, 10(2):144–174.

Chapter 11

Commercialising agroforestry to broaden the market share for smallholders in the South Pacific

Helen Wallace, Bruce Randall, Jimmy Rantes, Raywin Ovah, Birte Nass-Komolong, Craig Johns, Kevin Glencross, Cherise Addinsall, Wayne Hancock, Chris Cannizzaro, Shahla Hosseini-Bai, Paitia Nagalevu, Kelly Inae, Votausi Mackenzie-Reur, Doni Keli and Luke Fryett

Abstract

About 80% of people in the South Pacific are smallholder rural farmers with mixed-species or agroforestry systems, and little access to distant markets. Processing and adding value can stabilise agroforestry products, increase the shelf life and enhance market access, especially if processed locally. However, a market-driven approach is needed to identify opportunities for value-added products. Moreover, a well-functioning value chain is critical to business competitiveness and long-running sustainability.

In this chapter, we discuss transdisciplinary research to identify opportunities in the fruit, nut and honey industries, along with the options for adding value and for small-scale food processing. New value-added agroforestry products were developed with local processors in Vanuatu and Solomon Islands. Products in Solomon Islands include 3 types of nuts (*Canarium*, *Terminalia* and *Barringtonia*), muesli, dried banana, dried pineapple and dried pawpaw. Products in Vanuatu include chutneys, jams, manioc flour and dried banana. About 750 farmers were supplying to the processors at the end of our project, compared with fewer than 100 farmers before the project. Training in adding value was provided to over 700 participants (mostly women) in Fiji, Vanuatu and Solomon Islands. Initial training on food safety, food preservation, selling ‘up the chain’, and developing new products and value-chain techniques was provided to market vendors. An intensive 6-week training workshop in Fiji was then provided to 48 women. More than half of these women were engaged in the commercial sale of chutneys and jams at the end of the training. In Solomon Islands, women increased the value of their nuts, selling value-added nuts for about a threefold value compared to the value of raw products before the training.

The project has had a range of economic impacts, especially for female smallholders, especially in Fiji, Vanuatu and Solomon Islands. Project activities enabled both smallholders and processors to access new markets, which increased their income and sales up until the COVID-19 pandemic in March 2020. Disruptions to the economy caused by the pandemic highlighted the need for more value-added local food for food security. In Fiji, people traded food and bartered processed local food when many people were out of work.

Introduction

In Papua New Guinea (PNG) and the wider Pacific islands region, most people in rural areas sustain their livelihoods from agriculture, fishing and forestry. More than 90% of rural people are semi-subsistence smallholder farmers, and women are often primarily responsible for farming activities. Improved food security and sustainable forest management are regional priorities. We explored opportunities for new value-added agroforestry products to improve livelihoods in PNG, Vanuatu, Fiji and Solomon Islands. In Fiji and Vanuatu, we also investigated integrated agroforestry systems that are likely to have environmental benefits, such as catchment revegetation, and provide economic returns to smallholders. These agroforestry systems have potential to generate income and give smallholders greater access to remote markets, thus enhancing self-reliance, increasing environmental benefits and reducing poverty. Our transdisciplinary team, with collaborators from Griffith University, the University of the Sunshine Coast, The University of Adelaide and Southern Cross University, worked with government departments, non-government organisations and private sector processors.

Our research aimed to enhance opportunities for women to engage with the private sector. Women play a central role in household food gardening, growing and tending to agroforestry crops, and marketing horticultural and agroforestry crop products. A series of stakeholder workshops had strongly endorsed the need for development of agroforestry cropping systems. We conducted the research and worked with the private sector to create opportunities throughout the value chain for new processors and marketers, for a range of locally produced value-added products from agroforestry crops. The project team trialled a range of interventions, including market research to determine the best opportunities, new value-adding techniques and products, capacity building, particularly among women farmers and microenterprises, and business mentoring. Pilot sites were established in Fiji and Vanuatu to demonstrate agroforestry services and determine which crops had the best market potential. The specific objectives of the project were as follows:

- Identify multipurpose agroforestry crops with market potential for adding value in all 4 countries (PNG, Solomon Islands, Vanuatu, Fiji).
- Enhance the ability of small-to-medium-sized enterprises to participate in value adding (PNG, Solomon Islands, Vanuatu, Fiji).
- Enable smallholder and gender-equitable participation in agroforestry crop production (Vanuatu, Fiji).
- Pilot test catchment revegetation systems linked to markets (Vanuatu, Fiji).

Our approach

The project took a dual approach of addressing both the 'market pull' and the biophysical, economic and social needs of agroforestry systems. The market pull approach aims to ensure that markets exist for products and that the species promoted for planting improve smallholders' livelihoods. This provides more confidence and incentive for smallholders and processors to invest in both planting and adding value. The biophysical, economic and social aspects of agroforestry crop production were addressed, in tandem with the market pull, to give smallholders confidence that plantings will produce an income in an integrated system with a variety of crops. We analysed smallholder surveys early in the project to better understand the value chain, adoption behaviour, farm practices and decision-making. The catchment revegetation pilot projects were conducted only in Fiji and Vanuatu, where there has been a clear and urgent need to improve catchment revegetation to improve water quality and reduce the impact of flooding. In addition, our research examined the agritourism value chain by facilitating discussions between smallholders and the tourism industry.

Key results

Our transdisciplinary team researched market opportunities and value-chain constraints for a suite of agroforestry products. Commercial, cultural and environmental drivers were considered as part of the value-chain analyses. The research identified opportunities in the fruit, nut, honey and tree nursery industries and then focused on appropriate value-adding, small-scale processing and drying techniques as key enablers of industry development. We used an integrated value-chain approach and were truly transdisciplinary, with researchers from different disciplines working together to address project challenges and create new knowledge. This approach resulted in several new value-added products and produced livelihood benefits for many stakeholders. These benefits included:

- new nut products (Solomon Islands)
- linked processers and export markets (Vanuatu)
- women's nurseries to support tree planting and improvements to coffee production (Fiji)
- resources to help smallholders produce honey (PNG).

Identifying multipurpose agroforestry crops with market potential

In the first year of the project, the team assessed the needs of the private sector. Previous ACIAR projects in the Pacific had demonstrated that value-added products from agroforestry crops can enhance livelihoods (Wallace et al. 2022) and the stakeholders interviewed for our project strongly endorsed the need to develop and demonstrate agroforestry cropping systems that provide livelihood benefits and address issues in degraded catchments.

Research in the first year also highlighted that methods were needed to enhance opportunities for women and that smallholders need to be confident that the agroforestry produce will be both profitable and socially acceptable. Short-term cash flow is needed to provide return on investment while the tree crops are growing.

High-value agroforestry crops were chosen from the selection criteria according to their economic (market), social (cultural) and environmental potential (Bai et al. 2019a, 2019b, 2021; Hosseini-Bai et al. 2019).

For PNG, the main crops with market potential identified were:

- dried fruit – Dried rather than fresh fruit addresses issues with cold chain logistics, while building on opportunities with commercial partners. Crops with most potential include pineapple and mango.
- honey – This links to an existing ACIAR project on the impacts of mites on productivity and to ACIAR's *Canarium* project which encourages retailers to take more locally produced products.

For Fiji, the main crops with market potential identified were:

- coffee – This leverages supply opportunities with commercial enterprises such as Bula Coffee, with trials including both wild coffee and coffee planted in differing agroforestry systems.
- dried and processed fruit and nuts – Of particular interest are breadfruit flour and 3 nut varieties – tavola (*Terminalia catappa*), ivi (*Inocarpus fagifer*) and vutu (*Barringtonia edulis*). Drying can improve shelf life and avoid cold chain logistics issues.

Agritourism also offers potential across the agroforestry trial sites for the various crops, linking resort restaurants to producers and their environmental and production stories.

For Vanuatu, dried and processed fruit and nuts were identified as the main crops with market potential. Techniques for cracking nuts and drying both fruit and nuts were explored in integrated agroforestry cropping systems with several products – *Canarium*, *Terminalia,* Tahitian chestnut, *Barringtonia*, breadfruit, mango, cocoa and pineapple.

For Solomon Islands, processed and dried nuts were identified as the main crops with market potential. Strong links were possible with other ACIAR projects in PNG on drying techniques for nuts, particularly *Canarium*, *Barringtonia*, king tree and Tahitian chestnut.

In the short and medium term, smallholders need incentives and training to encourage them to invest in tree crops. They need to be given the confidence that agroforestry will produce income. They need to strongly engage with the private sector, and small-scale entrepreneurs need to be encouraged to add more value to products. In Fiji, in particular, our surveys identified that farmers mainly sell in markets or roadside stalls to buyers because they pay cash. Most of the decisions are made by the wife and husband together. Female respondents were primarily alone in making decisions about their children's health and education and the household's livelihood strategies.

We used a survey of Oxfam customers to gain insights into the purchasing patterns of ethical Australian consumers, and the potential for developing the value chain and exporting products from the Pacific to Australia. Results from the survey indicated that 90% of Oxfam customers believe that giving back to communities in need is very important. They are willing to help but want high-quality and unique products (80%), they prefer foods with pure or natural ingredients (75%), and they enjoy travel and supporting places they have visited (64%). Their main motivation to purchase products from the Pacific is the 'story behind the product'. This information was disseminated to producers in Fiji, Vanuatu and Solomon Islands. Our project used this information to support industry partners to improve packaging and labels to tell their unique story.

When considering what recommendations to make from a study such as ours, it is useful to understand the consumer profile. The target market tends to be mainly women, who have a high level of education, are more mature in age, are either working or retired, belong to a middle-to-high-income group and might purchase products only every few months or once a year. While price is always going to act as a driver, enterprises in the Pacific need to keep in mind the importance that this target group put on the 'story' of the product and the 'brand' of the retailer. While certification can drive consumer purchasing behaviour, the retailer brand can prove just as strong in communicating some of the values found within certification schemes.

Enhancing the ability of small-to-medium enterprises to participate in adding value

Value-adding opportunities in 3 of the 4 countries focused on drying tree nuts as they are rich in protein, improve food security and do not require cold chain logistics. Processors were particularly interested in *Terminalia, Barringtonia* and *Canarium* spp. because these species offer a range of raw products that they can process in their factories during different seasons (Bai et al. 2021). For similar reasons, processors were also interested in drying fruit. Coffee and honey were also identified as opportunities for adding value.

Key research gaps in adding value were identified in each country and are described below.

Fiji

A coffee producer, who was purchasing wild-harvested coffee beans, was interested in improving coffee genetics and increasing production. The project provided advice and equipment for drying beans to maintain quality, and advice on developing new packaging. This has resulted in expansion of the business and export sales.

The demand for trees for reforestation in Fiji is strong and the project team identified an opportunity for the Nadroumai Women's Club to propagate trees and sell them. A further opportunity was identified to provide training for women selling fresh produce in the market to add value and market their produce to customers up the chain. These customers needed reliable and consistent high-quality produce, food safety, labels listing ingredients, and high-quality packaging.

Vanuatu

A processor expressed interest in adding tree nuts and fruit to their facility as part of an integrated agroforestry crop system. Research gaps on drying methods, composition and nutritional analysis for products developed were also identified. Another producer identified a need to access export market opportunities for single-origin chocolate.

Solomon Islands

The tree nuts of interest to processors were ngali (*Canarium indicum*), alite (*Terminalia catappa*), and katnut (*Barringtonia* spp.). Specific research needs included drying methods and technology, and new product development. Nutritional and compositional analysis of developed products and solar drying technology was also required, along with nutritional analysis of dried fruit (pawpaw, pineapple, banana and muesli).

Figure 11-1: Kelly Inae demonstrates beekeeping techniques in PNG.

Papua New Guinea

On behalf of beekeepers, the project team researched floral sources of honey and the impact of agroforestry species on bee nutrition.

Value-adding interventions and technologies researched

The project team researched a range of interventions and technologies for the value-adding opportunities identified above. Some key areas of research were:

- Variability in nut size and kernel size – Larger kernels increase the return for effort for both farmers and processors, and the ratio of kernel to shell is an important parameter of nut quality (Herbert et al. 2019; Kämper et al. 2021; Trueman et al. 2022). Samples of *Barringtonia*, *Terminalia* and *Canarium* fruit were collected from Solomon Islands, Vanuatu and Fiji to assess size. The study clearly highlighted that tree selection for commercialisation of *Barringtonia* spp. needs to be at the country level, and perhaps even at village level.
- Chemical composition of nuts – Analyses of nuts provided information to processors on the health benefits, nutritional analysis and shelf life of value-added products (Bai et al. 2017b, 2019a, 2019b, 2021).
- Drying techniques for fruit and nut products – Drying stabilises the products, giving farmers and producers more time to store and sell their produce. This was especially critical for ensuring the quality of coffee.
- Nutritional analysis of products – This is required for labelling for up-chain customers, particularly export markets.
- Microbial analysis – This ensured processors' methods were safe and gave consumers confidence in the food safety of the product.
- Bee and honey research on floral sources – In PNG this research identified the potential for a niche honey industry based on rainforest honey. The research showed that honeybees collect pollen and nectar predominantly from tree species, even in landscapes where there are few trees. Agroforestry timber species could integrate beekeeping with agroforestry practices in PNG. Furthermore, forests provide bees with diverse fatty acids that help to keep them healthy. The research showed that beekeeping in PNG would benefit from preserving remaining forest cover and incorporating more trees into existing open landscapes to optimise the diversity in honeybee diets (Cannizzaro et al. 2021, 2022).

A review of the literature revealed that in Melanesian countries women are often underrepresented in value adding. Social-cultural factors reduce women's participation, such as access to resources, land, financial services, markets and education, as well as serious time constraints due to household and parenting duties. While women's involvement in microenterprise and employment is increasing, addressing these social-cultural factors could help create employment opportunities.

The project also explored opportunities for linking with the tourist industry using incentives such as payment for environmental services.

And for investing in value-adding of agroforestry products, we found that processors and financial institutions need confidence that there is a strong business case.

Building the capacity of smallholders and processors to add value

Training workshops on business development and management for small-scale entrepreneurs and small-to-medium-sized enterprises were conducted in each country. The training improved the capacity of participants (especially female smallholders) to operate microenterprises based on value-added products.

A series of workshops were designed and delivered to share knowledge on small business management, food safety, value adding and food preservation. Firstly, for women who sell fresh produce at the market, the team developed a training program on growing their business. The women were trained in value-adding techniques to extend the shelf life of products, sell to alternative markets and increase the unit price of products, thus increasing income and allowing them to diversify their microenterprises. This training was delivered initially in Solomon Islands by the project team but then further developed with the Fijian company, Food Inspired.

Training of women market vendors was conducted in collaboration with the Markets for Change program, a UN Women initiative in partnership with the UN Development Programme. Initially, 12 workshops were conducted in Fiji, with 401 participants. These workshops were so well attended and the workshops were so highly valued by UN Women that they sponsored additional training workshops in Vanuatu and Solomon Islands. In total, 529 women and 87 men received training through this program.

Feedback from participants in the initial training was that the training did not contain enough hands-on experience and did not allow enough time to build skills, confidence and experience. Consequently, Food Inspired were commissioned to provide more in-depth training and mentoring to a smaller group of women from a Lautoka social housing project. This new training was conducted as multiple training workshops over 6 weeks with small groups. The training covered food safety, Fiji food legislation, practical food preparation, packaging, skills for starting and managing a microbusiness, and sales and marketing. Participants had opportunities to sell their products through market days. Of the 48 women who started, 42 participants completed the training.

Figure 11-2: Women market vendors from Lautoka, Fiji, and Craig Johns (co-author of this chapter, centre-front) celebrate the conclusion of a series of training workshops for women on adding value to agroforestry products.

Impacts of the training on adding value for smallholders and processors

Fiji

In Fiji, the project resulted in more women adding value to agroforestry products, with 449 participants receiving training in value-adding techniques. From the intensive training of 48 women, at least 4 women immediately commenced trading and an additional 20 women followed when they witnessed their peers' success. A follow-up questionnaire revealed that 70.9% of respondents made some value-added product in the 30 days post-workshop and 54.8% of respondents made value-added product and were engaged in commercial sales. One participant's first batch was made in only one day and completely sold out; another participant made 90 Fijian dollars (US$39) in the first week and $60 (US$26) in the second week. There is growing interest from shops and resorts in buying from local markets.

Vanuatu

In Vanuatu, many new products and markets resulted from the interventions:

- New agroforestry products – The new products include chutneys, jams, manioc flour and dried banana. The project team assisted a local processor with business mentoring, research on drying, nutritional analysis, microbial analysis, packaging and labelling. As a result, the processor developed several new products, such as gluten-free cookies and nut products, and sold them through supermarkets and hotels. The processor's purchase of nangai nuts and other raw materials was providing economic benefits to between 400 and 700 farmers at the end of the project in 2020 (compared with 100 farmers at the start of the project in 2015). Before the COVID-19 pandemic, production of value-added products had increased (taro chips by 130%, tamarind products by 16%, mango products by 105%, dried nangai products by 17%). In 2019, nangai nut sales had increased from 1 to 2 tonnes of processed kernels; however, Tropical Cyclone Harold destroyed many of the nangai trees on Malo, resulting in the processor sourcing nuts from Malekula, Tongoa, Paama and Epi islands. Following the disruption to tourism in Vanuatu (the largest market for value-added products) due to the COVID-19 pandemic, sales from January to July 2020 were severely impacted, falling to just 0.6 tonne.
- New export markets for processors in Vanuatu – Through negotiations with Oxfam during 2018, a local processor achieved AUD17,490 (US$11,051) in sales of chocolates and coconut oil. Trade Aid (NZ) expressed interest in flour, chips, dried fruit, chutneys, jams, relish sauces, desiccated coconut, coconut oil and tea from the Pacific islands.

The project also helped form the Vanuatu Sustainable Tourism Policy (2019–2030) which aims to increase use of local produce within the tourism market. Goal 4 of the policy targets sustainable and responsible tourism to attract responsible high-value tourists, and support sustainable, ethical, local agricultural products and experiences. By increasing links between the agriculture, handicrafts and tourism sectors, the benefits from tourism will be shared between a broader range of stakeholders. The project has had a huge impact in supporting government action and has increased the skills of the government employees involved (Addinsall et al. 2022).

Solomon Islands

In Solomon Islands, a local processor made use of our drying research to develop several new products, such as dried *Terminalia* nuts ('Island crunchy'), dried *Barringtonia* nuts ('Island milky'), dried *Canarium* nuts ('Island soft'), muesli, and dried pawpaw, pineapple and banana.

The project also increased the processor's capacity by providing information on storage, nutritional analysis, microbial testing, product label design and packaging. The processor bought nuts and fruit from over 41 farmers, whom they have trained in post-harvest handling. As a result, during the life of this project they increased production of value-added *Barringtonia* and *Terminalia* nut products and developed a new product range. Before the COVID-19 pandemic, they were buying almost a tonne of nut products.

In all, 110 participants received training in techniques for adding value. Following training delivered by the processor to a women's group at Kolupa village, the group is now producing value-added products using their own *Barringtonia* and *Terminalia* nuts. This village was previously providing only raw materials to the processor.

The COVID-19 pandemic seriously affected tourism in Solomon Islands, closing most of the hotels and markets that sell dried nuts. Before 2018, the processor was buying raw nuts from more than 20 farmers each year, but since COVID-19 they have bought from only 5 farmers. This has impacted the livelihoods of the remaining farmers.

Figure 11-3: Dried fruit products and muesli from a new product range in Solomon Islands, enabled by research on drying techniques and information on storage, nutritional analysis, microbial testing, product label design and packaging

Figure 11-4: Women from Kolupa village, Solomon Islands, with their dried value-added nut products

Processors who are currently producing value-added *Canarium* nut products could increase their output and their income by also processing *Barringtonia* and *Terminalia* nuts, which are currently cottage industries servicing domestic market demand. Sales of indigenous nut products in Solomon Islands and Vanuatu have been strong, with supply unable to meet consistent repeat demand. This unmet demand in the domestic market for nut products indicates that this sector will continue to expand and provide opportunities for export opportunities. Several processors have already been experimenting with the export market.

Table 11-1: Annual volume (kg) of raw ngali, alite and cutnut purchased by Jedom Trading, Solomon Islands (2016–2021)

Year	*Canarium* (ngali)	*Terminalia* (alite)	*Barringtonia* (cutnut)
2016	Not available	Nil	Nil
2019	500	270	220
2020	279	190	146
2021	20	11	Nil

Papua New Guinea

In PNG, the project identified important honeybee flora of the Eastern Highlands. The findings have been used to publish a floral guide to beekeeping that has been distributed throughout PNG (Cannizzaro et al. 2021). The book is a full-colour visual guide with instructions and information on pest management, honeybee flora identification for pollen and honey, and helpful notes for beginner beekeepers. The book has been translated to Tok Pisin.

Enabling smallholder and gender-equitable participation

Land tenure is a serious barrier to women's involvement in agroforestry because planting trees constitutes a land claim. There is a movement in developing nations towards questioning globalisation, which has created some of the greatest levels of inequality for rural smallholders (Sader 2009). Secure tenure on land is the single most important condition for economic empowerment (FAO 2010). Social-cultural factors that influence women's disadvantage in agroforestry value chains include access to resources and land; access to extensions and financial services and markets; the physical nature of value-chain activities and cultural norms; customary and formal regulatory arrangements; and the limited benefit seen from agricultural research and development (Addinsall 2017).

In Fiji, 89.75% of land is under iTaukei (Indigenous or customary) title, about 6% is freehold land and about 4% is state-owned land. In Vanuatu, 99% of land is held under customary tenure. Leasing land in Vanuatu is more complicated than in Fiji as custom boundaries and identification of owners has not been formally documented. Key insights into opportunities for increased uptake of agroforestry systems have emerged:

- Introducing agroforestry systems into long-term existing leased land (more than 50 years) or aggregating customary land-owning groups to increase tree-crop production from many small plots and thereby selling produce in a coordinated way.
- Introducing more tree crops into a mixed agroforestry system.
- Engaging women within the agroforestry value chain through collective charitable activities or microenterprise activities that do not require land tenure; for example, collecting seed for growing seedlings in community-managed nurseries, collecting nuts for selling in local markets and local agribusiness, undergoing training in adding value to produce (such as honey, jams, nuts) for local markets.
- Strengthening links between the tourism sector and smallholders to build a long-term market; for example, through policies such as a 'payment for environmental services' levy.
- Encouraging tree planting in buffer zones where regulations require tree cover for ecological protection, but also where access to water is more secure.
- Using finance for catchment regeneration to plant productive tree species that can control erosion, but also provide livelihood opportunities for farmers.

In Vanuatu, the project team were part of national efforts to encourage increased local produce within the tourism market through the development of the Vanuatu Sustainable Tourism Policy (2019–2030). Policy objectives support an increase in local produce, much of which could come from agroforestry systems.

The project team explored how women could be drawn into those activities that add the most value. Addressing land tenure constraints and, in particular, rights for women to access land should not be confused with the push for reform of customary ownership of land (with the replacement of freehold or individual title) by neoclassical economists who see customary ownership as a critical barrier to economic growth. Consequently, the project sought to explore methods that can support agroforestry uptake while increasing access for women without displacing or eroding customary tenure.

Our research revealed that women's participation in agroforestry was usually limited to low-value occupations. Factors that increase women's disadvantage in agroforestry value chains include access to resources, finance and markets, and cultural expectations.

In Vanuatu and Fiji, agroforestry systems (containing local nuts, spices, cocoa, copra and coffee) are more supportive of women's livelihoods than formalised monoculture cash cropping. In Fiji, harvesting wild coffee and selling it through Bula Coffee is providing women direct economic benefit. Improving coffee production by planting, thinning and pruning trees would change coffee from being a wild harvest to a community asset, whereby the women would lose the direct benefit. Our work with Bula Coffee also included providing advice and resources to improve post-harvest drying, support for improved pulping and drying, and sharing information with growers and roasters in Australia and Vanuatu. As a result of project activities, Bula Coffee has gone from sourcing wild-harvested coffee from just one village at the start of the project to working with women from 82 villages.

New income opportunities for women, based on plant nurseries

To address issues surrounding women's involvement in income-generating activities and disseminate information from the project to women, the project team identified that the supply of high-quality seedlings is a major barrier to upscaling tree-crop production in Fiji and Vanuatu. Without land tenure women cannot plant trees, but they can collect seeds and grow seedlings. And nurseries also do not require a large time commitment that would only add to their household duties. Our project has established nurseries in Nadroumai (Fiji) and Port Vila (Vanuatu) to create employment opportunities for women in value-adding and agroforestry, opportunities that avoid some of the major problems.

Discussions with the women's group in Nadroumai led to the establishment of a nursery, which they run. Training programs on basic nursery practice, business management and improvements to the nursery were delivered. Training issues for the village women included time constraints due to family and community obligations, and a serious lack of financial resources.

The Nadroumai Women's Club nursery was established as a part of the project activities. Prior to this, the club received finance through member donations of one Fijian dollar (US$0.44) per meeting; now it receives regular income from seedling sales and has money in its bank account for community infrastructure projects. At the conclusion of the project in 2020, the nursery was fully functioning without the project team's support, the nursery had doubled in size, and more than 30 women were engaged in the day-to-day running of the nursery. This has assisted the community at a time when many people in Nadroumai have lost their employment in the neighbouring Shangri-La resort as an outcome of COVID-19 border closures. After the project ended, the women's nursery continued to bring them livelihood benefits (Addinsall et al. 2023).

Figure 11-5: **Kelerayani Vaqalo (right) and fellow members of the Nadroumai Women's Club in their nursery at Nadroumai, Fiji**

Pilot testing of catchment revegetation systems linked to markets (in Vanuatu and Fiji)

The project established 3 trial agroforestry sites in Fiji and Vanuatu to demonstrate production of food, non-timber forest products and timber. The trial was designed to include traditional and indigenous tree crops that had shown market potential (fruits, oils and nuts) and sandalwood. These sites – at Nadroumai village near Sigatoka (Fiji), Korubua community at Korotari near Labasa (Fiji) and Jubilee Farms on Santo Island (Vanuatu) – also demonstrate ecological services such as improved biodiversity and soil protection. In Fiji, both the Nadroumai and Korotari sites were clearly identified as urgently in need of improved catchment revegetation, for biodiversity conservation to improve water quality, and to reduce the impact of flooding.

At each site, between one and 2 hectares (ha) of tree plantings were established, integrated with cash crops. Tree crops take several years to produce marketable products and, as such, short-term crops (taro, pineapple, banana and sweetpotato) were interplanted with the tree crops to provide cash flow.

- At Nadroumai, a mid-catchment site, planting of one hectare began in 2016–2017 with about 350 trees and 200 seedlings from 8 species – tavola (*Terminalia*), ivi (*Inocarpus*), vutu (*Barringtonia*), vesi (*Intsia*), sandalwood, citrus, breadfruit and cocoa. Flooding in 2018 damaged the site, which was replanted with over 120 trees. Coffee seedlings and other cash crops were also planted. The total area developed over the project was 3.4 ha with another hectare fenced to reduce browsing pressure from livestock and wild pigs. All up, 38 members were involved with this site.
- At Korubua, a mid-to-upper-catchment site, planting took place on ex-sugarcane farmland adjacent to a forest reserve and river buffer zone, providing ecological remediation advantages. Planting began in 2018 with 500 fruit, timber and traditional nut trees, and 500 pineapples. Trees included sandalwood (yasi), citrus, tavola (*Terminalia catappa*), ivi (*Inocarpus fagifer*), vutu (*Barringtonia edulis*), *Calliandra*, vesi (*Intsia bijuga*), cinnamon, kavika, soursop and avocado. Cash crops included pineapple, passionfruit, kava, vegetables (tomato, eggplant, chilli), cocoa and coffee. In 2019, additional trees were planted bringing the total area under production to 3.4 ha. The focus was on engaging with young people through the 14 members of the Korubua Youth Group. During September 2020, 32 young people were trained in farm management, seed selection, propagation, grafting, marcotting and nursery management.

- At Mackenzie's farm at Jubilee Farms, a mid-catchment site, one hectare was planted in 2017–2018 with 400 trees, including natapoa (*Terminalia catappa*), nangai *(Canarium indicum)*, namambi (*Inocarpus fagifer)*, and smaller trees such as cacao and namamou (*Flueggea flexuosa). Canarium indicum* was a focus, due to the importance of the crop to the landowners (Lapita Café). Additional plantings were undertaken in late 2018 to replace losses due to the dry conditions. Cash crops included manioc, kava, vegetables, tropical fruits (banana, pawpaw), coffee and cocoa.

The project found that tree planting projects in the Pacific region are challenged by a lack of planting materials. Nurseries and training were identified early on as an opportunity to support other projects and for women to engage with agroforestry. Nurseries established in Nadroumai (Fiji) and in Vanuatu (by ACTIV, Alternative Communities Trade in Vanuatu) to support tree revegetation plantings provided women's groups with training in basic nursery skills, grafting and nursery management. Through this project, the nursery at Nadroumai has played a significant role in supplying 3,966 seedlings for the Global Environment Facility's Ridge to Reef reforestation project. To reafforest the catchment areas in Fiji, the Ministry of Forestry is raising 10,000 eucalyptus seedlings and 30,000 pine seedlings.

Floods, revegetation, soil loss and cyclones were environmental issues that arose while these sites were being established. An additional 3 sites were also investigated but raised issues of land tenure and willingness to participate.

Tourism operators and catchment revegetation

In Vanuatu and Fiji, there is a growing understanding within the tourism industry of the negative impacts of landscape degradation. Both countries have identified watershed protection and conservation as major priorities. However, there are few examples of systems that can help to protect vulnerable areas in key catchments from the impacts of severe climatic events (particularly flooding) and threats to water quality (nutrients and sediment). We explored the potential to obtain collaborative funding from major tourism operators for revegetation of catchments in the areas close to their facilities. Findings from the participatory action group and discussion paper were integrated into the Vanuatu Sustainable Tourism Policy (2019–2030).

The policy identifies the need for catchment protection and requests that the tourism sector adopt conservation management to protect key biodiversity areas. Active catchment revegetation is identified as one way that tourism operators can protect the environment. Our team worked with the policymakers In Vanuatu to develop standards for sustainable tourism and methods to fund investment in conservation. Negotiations with tourism industry stakeholders and cruise company representatives explored the introduction of payments for environmental services and a 'visitor arrival levy' for conservation activities.

In Fiji, tree clearing upstream from the pilot site at Nadroumai has created erosion problems for landholders in Nadroumai village, and sedimentation of the reef affects the Shangri-La resort downstream. Catchment revegetation is urgently needed, but there are land tenure issues associated with planting trees. Negotiations between the Shangri-La resort and the Nadroumai Women's Group for supply of seedlings and catchment revegetation progressed until Shangri-La management decisions placed the catchment regeneration project on hold.

Strengthening links between local producers and the tourism industry

A largely unrealised market exists in supplying local produce to the tourism market. Tourism businesses often operate around local communities and are generally keen to promote local foods — as a point of difference in their products and to reduce the high cost of imported food. Major barriers are consistent quality and reliable supply. Small-scale agroforestry does not always produce the volume and consistency required, and the geographically dispersed source of supply makes it difficult for buyers to access local produce. Major constraints to supplying the tourism industry with locally grown produce are:

- **Quality** – Improving local varieties to suit the tourism sector's needs requires support and extension services not always available to smallholders. Improving options for transport of fruits is also a challenge.
- **Consistency** – Discussions with operators such as the Shangri-La resort in Fiji indicated that seasonality was not a concern, but the reliability of supply when crops were in season was.
- **Coordination** – As described by the head chef at the Shangri-La resort, sourcing local produce was a priority, but a challenge, given poor coordination by intermediaries who deliver the produce. Where farmers' cooperatives or coordination between multiple farms exists, buyers would prefer to go direct to the farmers. However, the project has worked with ethical intermediaries, who provided a key service in quality control, supply assurance, training, extension services and overall coordination of supply. Such actors heighten opportunities for long-term beneficial relationships between producers and the tourism industry.

The project has made a very large impact in supporting government action towards encouraging demand for local supply of produce to the tourism industry in Vanuatu through the development of the Agritourism Diversification Strategy, which meets key criteria in the Vanuatu Sustainable Tourism Policy.

Figure 11-6: Participants in the intensive value-added training from the Savusavu community in Fiji

Impacts of COVID-19

Bringing new sources of income to rural families has had positive social impacts for smallholder farmers, particularly women. However, the COVID-19 pandemic has disrupted markets and product demand. The disruptions to the economy caused by the pandemic highlighted the need for more value-added local food in Pacific countries and also created opportunities. Food security emerged as a major concern and processing local food to increase its shelf life and add value is seen as a way to improve livelihoods, produce income and substitute for imported food that is no longer affordable or available. In Fiji, Food Inspired provided market women with further training in adding value as a way to improve their livelihoods. Food trading and bartering flourished during the pandemic when many people were out of work. In Vanuatu 'satellite' food-processing training on outer islands was delivered as part of the project, in response to the COVID-19 crisis and Tropical Cyclone Harold.

Conclusions

This project demonstrated the potential of value-added agroforestry products to improve livelihoods of rural villagers in PNG, Solomon Islands, Vanuatu and Fiji. The research identified opportunities in the fruit, nut, honey and tree nursery industries and then focused on appropriate value-adding, small-scale processing and drying techniques as key enablers of industry development. The project also established pilot sites in Fiji and Vanuatu to demonstrate agroforestry services and determine crops with the best market potential. This project resulted in many new value-added products and produced livelihood benefits for many stakeholders. These new products and benefits included:

- new nut products (Solomon Islands)
- processers linked to export markets (Vanuatu)
- new processed products (Vanuatu)
- women's nurseries to support tree planting (Fiji)
- improved coffee production (Fiji)
- smallholders trained in adding value and marketing up the chain (Fiji, Vanuatu and Solomon Islands)
- new policies on agritourism adopted by key stakeholders (Vanuatu)
- resources to help smallholders produce honey (PNG).

The project has had a range of economic impacts, especially for female smallholders in Fiji, Vanuatu and Solomon Islands. Project activities have enabled both smallholders and processors to access new markets, and increased their income and sales as a result, up until the COVID-19 pandemic in March 2020. The disruptions to the economy caused by the COVID-19 pandemic highlighted the need for more value-added local food in Pacific countries.

A major strength of this project was the training of women in value-adding and nursery production. It has demonstrated to other donors the importance of quality training and of designing training that is appropriate for the participants to ensure lasting impacts.

References

Addinsall C, Glencross K, Scherrer P, Weiler B and Nichols D (2015) 'Agroecology and sustainable rural livelihoods: A conceptual framework to guide development projects in the Pacific Islands', *Agroecology and Sustainable Food Systems*, 39:691–723.

Addinsall C, Rihai N, Andre B, Addinsall E, Dunphy M, Van der Wildenberg B, Nelson A and Weir T (2023) 'Applying an intersectional lens to addressing gender disparities and disadvantage in rural Melanesian agriculture', *Journal of International Development*, 1–21.

Bai SH, Darby I, Nevenimo T, Hannet G, Hannet D, Poienou M, Grant E, Brooks P, Walton D and Randall B (2017) 'Effects of roasting on kernel peroxide value, free fatty acid, fatty acid composition and crude protein content', *PloS One*, 12:e0184279.

Bai SH, Brooks P, Gama R, Nevenimo T, Hannet G, Hannet D, Randall B, Walton D, Grant E and Wallace HM (2019a) 'Nutritional quality of almond, canarium, cashew and pistachio and their oil photooxidative stability', *Journal of Food Science and Technology*, 56:792–798.

Bai SH, Nevenimo T, Hannet G, Hannet D, Jones K, Trueman SJ, Grant EL, Walton DA, Randall B and Wallace HM (2019b) 'Freezing, roasting and salt dipping impacts on peroxide value, free fatty acid and fatty acid composition of nut kernels', *Acta Horticulturae*, 1256:71–75.

Bai SH, Randall B, Grant E, Gama R, Gua B, Keli D, Negalevu P, Oakeshott J and Wallace HM (2022) 'Tree-to-tree variation of kernel size in two underutilized tree nuts in Pacific', *Acta Horticulturae*, 1340:141–144.

Cannizzaro C, Inae K, Ovah R, Schouten C, Nass-Komolong B and Wallace H (2021) *Beekeeping in the Eastern Highlands of Papua New Guinea*, National Agriculture Research Institute, Morobe Province, PNG, ISBN 9980-932-99-6.

Cannizzaro C, Keller A, Wilson RS, Elliott B, Newis R, Ovah R, Inae K, Kerlin DH, Bar I, Kämper W, Shapcott A, Wallace HM (2022) 'Forest landscapes increase diversity of honeybee diets in the tropics', *Forest Ecology and Management*, 504:119869.

FAO (Food and Agriculture Organization of the United Nations) (2010) *Agriculture for growth: learning from experience in the Pacific: summary results of five country studies in Fiji, Samoa, Solomon Islands, Tonga and Vanuatu*, Food and Agricultural Organisation, FAO, Rome, Italy.

Herbert SW, Walton DA and Wallace HM (2019) 'The influence of pollen-parent and carbohydrate availability on macadamia yield and nut size', *Scientia Horticulturae*, 251:241–246.

Hosseini-Bai S, Trueman SJ, Nevenimo T, Hannet G, Randall B and Wallace HM (2019) 'The effects of tree spacing regime and tree species composition on mineral nutrient composition of cocoa beans and canarium nuts in 8-year-old cocoa plantations', *Environmental Science and Pollution Research*, 26:22021–22029.

Kämper W, Trueman SJ, Ogbourne SM and Wallace HM (2021) 'Pollination services in a macadamia cultivar depend on across-orchard transport of cross pollen', *Journal of Applied Ecology*, 58:2529–2539.

Sader E (2009) 'Post-neoliberalism in Latin America', *Development Dialogue*, 51:171–80.

Trueman SJ, Kämper W, Nichols J, Ogbourne SM, Hawkes D, Peters T, Hosseini Bai S, Wallace HM (2022) 'Pollen limitation and xenia effects in a cultivated mass-flowering tree, *Macadamia integrifolia* (Proteaceae)', *Annals of Botany*, 129:135–146.

Wallace HM, Hannet D, Hannet G, Hosseini-Bai S, Jones K and Komolong B (2022) 'Commercialising an indigenous agroforestry tree: overview of commercial processing methods for *Canarium indicum* (galip) nuts in Papua New Guinea', *Acta Horticulturae*, 1355:345–350.

Chapter 12

Enhancing private-sector-led development of the *Canarium* industry in Papua New Guinea

Helen Wallace, Shahla Hosseini Bai, Elektra Grant, Brett Hodges, Emma Kill, Bruce Randall, Birte Komolong, Carson Waaii, Dalsie Hannett, Godfrey Hannett, Simaima Kapi Ling, Craig Johns, Theo Simos, Tio Nevenimo, Kim Jones and Graham Ashford

Abstract

Nut trees in agroforestry systems have huge potential to improve livelihoods in developing countries. Only 5 species of nuts make up 90% of world trade even though global demand and consumption of nuts has doubled in the last decade. Many indigenous nut species have been domesticated in traditional agroforestry systems but have not been commercialised. *Canarium indicum* is an indigenous agroforestry tree of the South Pacific that produces nuts with high nutritional value, along with timber and shade for crop plants. This species is culturally significant to the coastal communities of Papua New Guinea (PNG) and has been traditionally processed for thousands of years.

We report on a series of projects in PNG that have developed semi-commercial processing methods for nuts of *C. indicum*. Research over 2 decades has developed systems that can be scaled up and adapted to large-scale processing. The key challenges that needed to be solved were systems and processes for de-pulping (removing the flesh around the shell), cracking (removing the nut from the shell) and drying. Consequently, we developed a variety of methods for both small-scale and larger-scale operations. In 2015, we set up a demonstration factory based on our processing research and tested the market demand for *C. indicum* nuts in PNG. The demonstration factory more than doubled production of processed nut products each year and by the end of 2018 over 1,300 farmers and entrepreneurs were selling nuts to the demonstration factory. Over 2,000 smallholders are now participating in the emerging *Canarium* industry in PNG, and this new industry has already improved livelihoods of smallholder farmers.

Introduction

Nuts have excellent nutritional value and, because they can be stored for long periods, they improve food security (Gama et al. 2018). Packaged nuts can be sold for cash, processed and exported to distant markets (Walton et al. 2017; Bai et al. 2019a). Globally, just 5 species – walnuts, hazelnuts, pistachios, almonds and cashews – make up more than 90% of the trade in tree nuts, though many other species of edible nuts have great commercial potential.

Canarium indicum (known as galip in PNG) is an agroforestry tree grown in eastern Indonesia and the Pacific region that produces edible nuts and timber (Nevenimo et al. 2008). In PNG, it has been domesticated in traditional agricultural systems for over 6,000 years (Matthews and Gosden 1997). The species is grown mostly in smallholder blocks or harvested from the wild. *Canarium* nuts have been the focus of efforts by donor agencies to commercialise the industry in PNG and the Pacific region (Wallace et al. 2022). In PNG, about 250,000 elite trees selected by the National Agricultural Research Institute (NARI) have been produced with funding from various donors, and distributed to smallholders and cocoa plantations.

These projects aimed to expand markets and processing of *Canarium* nuts in PNG's East New Britain province by strengthening private sector capacity. When the first commercialisation project commenced, the *Canarium* industry lacked private sector investment. Two major challenges to commercial investment were a lack of technical knowledge on processing and a lack of confidence that markets for *Canarium* products existed. Inside the fleshy fruit is the hard nut-in-shell which must be cracked to extract the edible kernel. Women do most of the *Canarium* nut-growing and trading activities, including cultivating, harvesting, processing and selling, so building an industry based on *Canarium* had potential to improve livelihoods for women smallholders.

In response, our project addressed 4 objectives:

- Assess the needs of the private sector to participate in the *Canarium* industry.
- Develop and undertake research-based interventions that address the needs of the private sector, including smallholders, small-scale entrepreneurs (especially women), small and medium-sized enterprises, and large-scale processors.
- Develop an appropriate commercial model for a medium-scale value-adding factory for the *Canarium* industry.
- Create a model for public–private partnerships in the *Canarium* industry in PNG.

Research locations and process

Our projects were mostly conducted on the Gazelle Peninsula, in PNG's East New Britain province, with some activities in the province of New Ireland, in Port Moresby, and in the Autonomous Region of Bougainville. Activities centred around a demonstration factory for processing galip nuts, based at NARI's Islands Regional Centre in Keravat, East New Britain.

To address the processing challenges and create new markets and products for galip nuts, we took a truly transdisciplinary research approach, with scientists, social researchers, economists, market specialists and nut industry experts regularly interacting, planning, and discussing challenges as they arose.

The project team adopted an adaptive action research methodology. Initially, this was planned on a yearly cycle, but adaptive planning was needed much more frequently as the challenges rapidly changed and the project evolved. In the first year (2016), the key challenges were lack of engagement by both smallholders and investors, technical challenges and lack of supply.

Financial analysis in the second year of the project recommended a buying price of 1.5 kina (PGK) per kg (US$0.4) at the factory gate. This encouraged smallholders to sell to the factory, and some technical challenges were then resolved, resulting in increased supply of raw material (nut-in-pulp) in 2017. Once processing challenges were resolved, the products were sold in local retail outlets, but supply could not keep up with demand in local markets. By 2018, smallholders were more confident and knowledgeable, and a strong supply of over 200 tonnes of raw material was purchased by the factory. There was also strong demand from markets in Port Moresby after the product launch in July 2018, with product often out of stock in the few retail markets where it was sold. However, the factory did not have the processing capacity to match either the supply or demand. In 2019, supply fell due to other processors entering the market coupled with a smaller production season. This illustrates how frequent recalibration and reassessment of the research directions were needed, generally involving integrated knowledge and teamwork from several disciplines.

Over 2,000 smallholders are now participating in the emerging *Canarium* industry in PNG, with 4 processors active in 2020 before the COVID-19 pandemic. In 2022, there are 2 active processors and an emerging industry selling a range of products into formal retail outlets.

Enabling private sector participation in the *Canarium* industry

At the start of the project in June 2015 there were no small-to-medium-sized enterprises (SMEs) or large-scale processors, and the only market participation was through women selling galip nuts wrapped in banana leaves in the informal markets. Three years later, over 1,000 smallholders, along with entrepreneurs and on-sellers, were selling to the demonstration factory. In 2022, 2 private sector processors were processing and selling *Canarium* products into formal markets.

Market research undertaken in year 1 (2015) of the project was directed at developing an understanding of consumer markets for local and imported nuts in PNG. We mapped the organised market channels available for potential distribution of galip nut in the main metropolitan cities of Port Moresby and Lae. The key findings were as follows:

- Nuts grown locally in PNG, such as peanuts, do not feature in organised retail or food service channels, and galip nut has historically not been commercially available. Most packaged peanuts and those used in local food production are imported from China.
- In regional areas where galip trees are highly prevalent, the nut forms part of the traditional subsistence diet, and small quantities of cracked nuts are sold at local markets and to tourists by women vendors. Product is available only during the harvest season. This form of product wrapped in banana leaf (*karamup*) was deemed by the project team as highly perishable with associated food safety and quality control risks. It was considered not acceptable for distribution in modern organised markets.
- Any new consumer product configured for new markets needed to satisfy modern food safety standards, product (organoleptic) efficacy, and have a storage shelf life exceeding 12 months at room temperature. Such a product would need to be packaged appropriately and meet specifications for modern transportation, handling and distribution systems. Accordingly, it would need to be positioned and priced to compete with an established range of imported nuts and snacks.
- The target market was defined to approximate 20,000 potential consumers – mainly high income earners in PNG`s capital, Port Moresby, including tourists and expatriates. Key market position attributes were communicated on the package and at point of sale.

- Industry consultation during year 1 found little confidence in the development of a locally sourced product without clear market pull and sustainable profit returns. Further concerns arose around consistency of supply, large gaps in technical knowledge and processing, low return on investment, and high fruit-sourcing costs that would require significant capital and market development investment.

These insights informed the research team about the forms of nut and packaging that could be developed in the demonstration factory and airfreighted to target markets. A *Canarium* industry roadmap was created at the start of the project, then revised and updated at the end of the project (Figure 12-1).

The knowledge of small-scale galip farmers and fruit collectors supplying the demonstration factory has steadily improved in relation to quality specifications. As the industry develops, the quality standards will need to be refined to reward farmers for producing nuts that have a high kernel-to-shell ratio (known as kernel recovery). Some entrepreneurs have entered the industry as regional buyers, and this sector needs further development and training in quality control.

The large-scale farmers and plantation sector require access to elite planting material, financial information, information on tree management, and the costs and benefits of interplanting *Canarium* trees with cocoa, combined with reliable information on market potential.

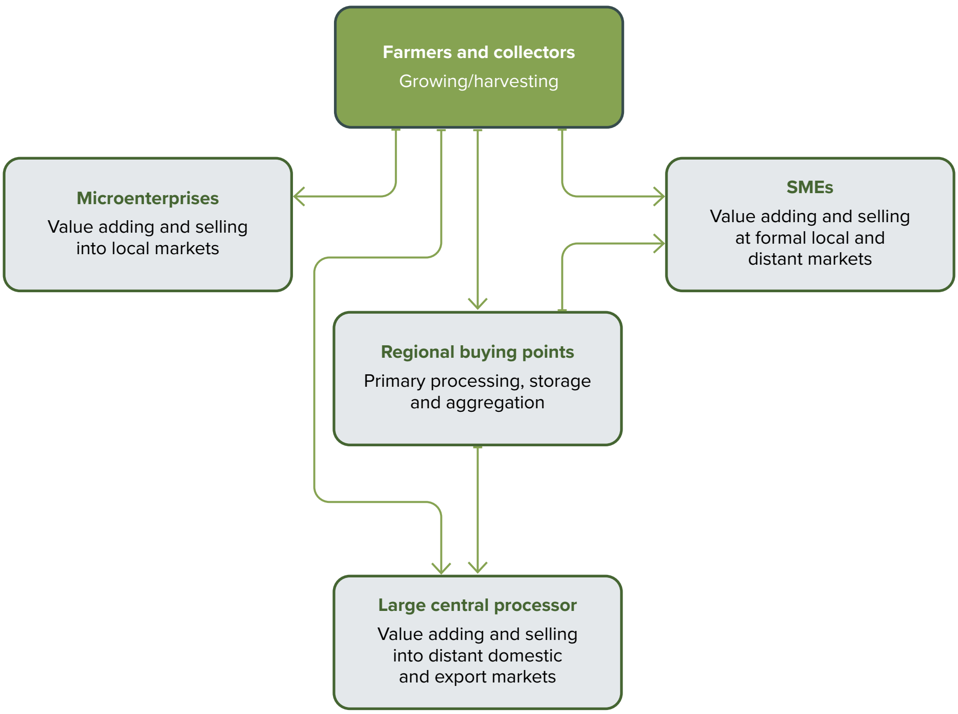

Figure 12-1: A schematic view of product flow through the future PNG galip industry

Priorities for training and extension to expand the industry were identified and the following needs were met through training workshops:

- Small-scale entrepreneurs needed training to improve processing, packaging and labelling.
- Small-scale entrepreneurs needed training to build economically viable, locally built crackers.
- Small-scale entrepreneurs needed training to build economically viable, locally built solar dryers.
- Female smallholders emphasised training for younger generations and requested marketing options for produce from their gardens.

Developing research-based interventions for smallholders and SMEs

Training was delivered for smallholders, small-scale entrepreneurs and SMEs, informed by our report on training and extension.

Research on refining methods for small-scale processing included cracking technology, de-pulping methods and processing methods. Three main methods were readily transferable:

- **Solar drying –** The project team built a small-scale solar dryer suitable for drying galip and other fruit and nut products (Wallace et al. 2016). Solar dryers were then built in 3 provinces of PNG using locally available resources. Different models have been transported across East New Britain, New Ireland, and the Autonomous Region of Bougainville, tied to the back of utility vehicles, in boats and on top of trucks. It has demonstrated the versatility and effectiveness of this simple design and how it can be easily modified to suit a situation.
- **Other drying options –** The team developed a range of drying options that can be used depending on access to electricity or gas. Simple procedures and tests were developed to ensure that galip nuts are sufficiently dry for them to be stored, using electric dehydrators, a range of ovens, and open fires and pans (Wallace et al. 2016, 2022).
- **Adding value –** Throughout the project, there were many opportunities to trial galip-based, value-added products, with ongoing work in the Galip Nut Company kitchen and with small-scale entrepreneurs.

A series of expos were designed and delivered to share project knowledge on drying, processing, packaging and shelf-life trials for female entrepreneurs. Through these expos, over 130 female entrepreneurs across the East New Britain and New Ireland provinces have received training and exposure to equipment, tailored to their community.

Food dehydration techniques were demonstrated, including with locally constructed solar dryers which were used to dry a range of produce. The techniques varied from solar drying and solar-assisted drying to domestic electrical dehydrating units, depending on the location of the community being trained and their access to electricity. A range of locally grown fruits and vegetables proved suitable for dehydration and storage, including mango, banana, tomato and nuts. Often, communities found different ways to use the technologies and adapt them to their own purposes, especially in the remote communities. For example, one community repurposed the solar dryer to dry the sea cucumber that they harvest and sell. Their feedback was that using the solar dryer avoided the smoke taint that reduces the price of this rare commodity. Another community used the wood-fired oven to bake bread weekly for sale to passing boat traffic.

Figure 12-2: Godfrey Hannett (co-author) training female smallholders on nut-cracking technology

Packaging demonstrations included the use of second-hand jars from local products through to the use of electric vacuum sealers. Again, these workshops were tailored to the community's access to electricity and packaging supply. Products could be dried and stored even in remote communities, extending the availability of seasonal food crops.

The storage of products in these scenarios also requires a solid understanding of health and hygiene to keep foods safe to eat. A standard component across the training events highlighted the importance of health and hygiene; this component was delivered in the local language, accompanied by an interactive presentation delivered in Tok Pisin. A tennis ball that had been rolled in glitter was handed between participants demonstrating the spread of contagions from hands through to food. Participants were astonished by the end of the day to see how far the glitter had travelled and how it appeared on nearly everyone's mouth, face, hands and clothes.

A project review was conducted each year and used to inform the following year's activities. Early in the project, key challenges were the lack of raw material, smallholders' lack of knowledge of how to sell, and SMEs' lack of interest in the industry. As the project evolved and the factory began buying nut-in-pulp, key challenges were increasing processing efficiency and getting products to market. By the third year, market demand was very strong and many farmers were keen to sell their produce to the factory, but the factory did not have enough processing capacity to cope with either demand or supply. SMEs entered the industry in the fourth year and supply of raw material became very limited. These challenges required the project team to constantly change and adapt their research.

Training women smallholders in Bougainville

In Bougainville, in collaboration with a Transformative Agriculture and Enterprise Development Program partner project, 'Improving opportunities for economic development for women smallholders in rural PNG', we identified training opportunities for women smallholders to share what they had learnt in the Family Farm Teams training delivered by our partner. These enthusiastic women were hungry for new income-generating ideas and our project team delivered training to about 53 participants. Active demonstrations included health and hygiene, baking breads and cakes, dehydrating and packaging food, developing the galip industry and making better use of the crops that are prevalent in the community.

Female smallholders were continually trained on the quality standards required by the factory at the point of purchase. The point of purchase was initially in the village, but later it changed to the factory gate when the buying model changed to factory purchase. This change was reinforced with posters, announcements on the radio, NARI booklets and product samples used to demonstrate standards required for the factory to purchase. The change was mainly about the colour and maturity of the produce and about harvesting and storage methods to preserve the quality of the galip before processing.

Large-scale events in the region were attended by the project team and used to train smallholders on post-harvest techniques required to sell to the factory. This included demonstrations and hands-on opportunities to use the mechanical cracker developed in the demonstration factory, presentations on the industry, and opportunities for farmers to engage in further training and sales to the factory. Mechanical crackers were set up to crack the smaller nuts that comprised the rejects from the factory and were made available at these large gatherings. Smallholders were encouraged to come and try a mechanical cracker for the first time. Many were interested in how they could sell to the factory and how they could access genetic *Canarium* material to plant on their garden blocks.

Training SMEs in processing and marketing *Canarium*

Early in the project no SMEs were interested in marketing *Canarium*, so the focus was on microenterprises and small-scale entrepreneurs. In 2017, we trained 25 small-scale entrepreneurs – who were already selling galip nut at local markets between Kokopo, Rabaul and Kerevat – in improving market access and capacity in the *Canarium* industry. They were taken on a tour of the facilities and then they participated in a value-adding workshop in the processing facility, to show how they could incorporate the techniques used in the factory into their own small enterprises. These techniques included simple moisture tests that they could carry out to ensure extended shelf life, packaging options and the benefits they provide, and some marketing ideas around labelling and brand identification.

Some training packages for microenterprises included:

- a food safety booklet produced for female entrepreneurs in the market
- a health and hygiene leaflet, in Tok Pisin
- food drying techniques and the 'snap test', a simple test to determine if nuts were dry enough that they could be stored for longer than one week
- a guide to preparing recipes, in Tok Pisin.

Later in the project, as SMEs and larger-scale processors became interested in processing galip, the training and information packages included a manual of factory standard operating procedures for training staff in procedures for producing high-quality *Canarium* products, and minimum standards for raw blanched and roasted galip nut.

The project actively worked with interested private sector processors across East New Britain and New Ireland, and hosted interested groups at the inaugural Canarium Buyers Reference Group Meeting held in Kokopo in April 2019. This meeting allowed everyone purchasing and processing galip to discuss concerns and challenges they had faced.

A group of farmers and others interested in developing a galip industry have formed the Galip Club. The group works across the Gazelle Peninsula in East New Britain with a strong focus on local sustainability and ensuring its members can benefit from the industry, whether they are looking to sell their nuts, are interested in propagation, or are seeking to add value. The club organises regular training opportunities and allows communities to decide what is best for them.

We have supported the Galip Club with a range of training, including factory tours, farm visits, agricultural methods, biochar production and composting workshops, and workshops on baking for profit. Training has taken place with representatives from each of the 4 wards that the club covers, and they have since taken the training back to their communities and shared these skills and knowledge.

Mentoring for microenterprises

We offered a mentoring program to 7 women who regularly sell galip in the Rabaul markets. They attended training at the Rabaul local government offices in March 2017, which covered financial literacy and value-adding opportunities. The Bank of South Pacific delivered tailored business plans and savings goals, including training in budgeting, covering not only their spending but also activities to optimise their incomes.

Two small-scale entrepreneurs, Doreen Frank and Anna Kopang, received further mentoring and assistance with packaging and labelling to develop their products. This initially resulted in the sales of packaged products with a longer shelf life through the local markets. In 2018, one of these women reported trialling the roasting of leftover nuts. However, these women have faced a range of obstacles, from access to facilities, such as ovens, to the local community's resistance to new ideas that step outside traditional activities, thereby attracting attention and social stigmatisation.

The project team had weekly contact with Devine Management Systems, a local SME, supporting and mentoring them on packaging, distribution, safe handling and marketing, so that they could bring sustainable PNG products to retailers in Port Moresby and sell them through their own shopfront stalls. Dorothy Luana, the proprietor of Devine Management Systems, has since become a great ambassador for the industry and role model for women in taking the next step to becoming a small enterprise.

Participants' feedback on training

Participants of all workshops and expos were hungry for knowledge and new ideas, not only for their own households and family members but also to give them options for saleable products at the local market. One male participant summed this up as, 'We don't have the access to these ideas in our homes. It is good to have fresh things to try.' Two younger female participants commented, 'These products are much better for our children because we can control what goes into them.'

Positive feedback from the Galip Expo held at the end of 2018 in New Ireland included reports of uptake of food preservation technologies and making of cordials and jams.

> The galip nut has been overlooked by locals but now we have come to know how important it is health wise and also to earn money. And the drying processes, especially the solar dryer is one that will be easier for storing dried food [and] meat for longer time. Food preservation is a big area we lack.
>
> — A male participant

Positive unexpected outcomes from some of the training workshops included some gender equality, role-reversal scenarios with several men explaining that they had never before had to prepare vegetables. Many complained how hot it was when cooking over an open fire. ‘I have to apologise to my wife,’ one male participant commented. ‘Cooking is really hard work.’

Figure 12-3: Galip nuts before and after de-pulping. Removing the fleshy fruit to extract the nut-in-shell is the first step in commercial processing of galip nuts.

Figure 12-4: The dried, hard nut-in-shell is cracked to extract the edible kernel.

Developing a commercial, medium-scale factory for adding value to *Canarium*

In 2015, our project began the process of setting up a demonstration processing factory, which produced commercial *Canarium* nut products. Critical infrastructure for large-scale processing of galip nuts was developed over several years, including mechanical crackers and solar-assisted dryers. In 2018, commercial galip products were tested in formal markets and demand was very strong. The factory was unable to meet demand for the products. Then, in 2019, 4 SMEs began processing and marketing galip nut products.

Research on appropriate processing methods

Researching and refining appropriate methods for medium-scale and large-scale processing formed a major component of the project. Commercial processing of galip nuts has 3 main steps (Wallace et al. 2010, 2016):

1. Remove the fleshy fruit to extract the nut-in-shell, also called de-pulping.
2. Dry the nut-in-shell to stabilise the nut and allow it to be stored.
3. Crack the hard nut-in-shell to extract the edible kernel.

An optional fourth step is to remove the testa – the papery cover of the creamy white kernel. This is optional as the kernel can be sold and eaten with the testa on.

The project researched large-scale storage methods, mechanical crackers, testa removal methods, mechanical pulp removal (Bai et al. 2022), and nut drying methods.

Some critical interventions were:

- **De-pulping** – The demonstration factory at NARI Kerevat tested various methods for removing the pulp, including a cement mixer with some stones and metal, tyre de-pulpers and other machinery. The best solution was a modified fruit-juicing machine. The machine can de-pulp 2 to 3 tonnes of nut-in-pulp per hour with at least 3 people. Previously this would have taken a full day with 5 to 8 people. The modified machine has reduced the labour and resources put into de-pulping by more than half. The project also supported the development of motorised de-pulper prototypes that can de-pulp without the soaking stage, opening the opportunity for further efficiencies.
- **Drying** – Drying options were developed for areas with and without access to electricity. A large-scale nut-in-shell dryer was designed for the demonstration processing factory (Figure 12-5). The dryer was constructed using a decommissioned refrigerated container and local materials. It uses a small 2-kW heating element and passive solar heat, and can successfully dry about 4 tonnes of nuts per week. A small-scale solar dryer was also used to dry cracked galip kernel in a village without electricity. This solar dryer reached temperatures of above 50 °C and dried kernels to about 4.3% moisture content in 5 hours and 1% in 7 hours.

- **Cracking** – A mechanical cracker and processing line was commissioned to increase cracking capacity at the factory. A modified mechanical cracker from the macadamia industry was installed, tested and adjusted (Figure 12-6). A series of trials were undertaken to test the efficiency of the cracker and adjust for different size galip nuts. The large-scale cracker resulted in about 50% whole nuts. A significant challenge remains to engineer the cracker for large-scale processing without damaging the nuts. The best option was small hand-operated benchtop crackers with modified blades (Figure 12-7). They produced between 80% and 90% whole undamaged nuts when operated by an experienced cracker compared to about 50% whole undamaged nuts with mechanised crackers. However, these crackers require labour and improvements to better comply with occupational health and safety provisions.

Figure 12-5: (Left) A large-scale nut-in-shell dryer constructed from a decommissioned refrigerated container and local materials. (Right) Inside the large-scale dryer.

Figure 12-6: Mechanical cracker and the processing line commissioned to increase cracking capacity

Figure 12-7: (Left) Small hand-operated benchtop crackers with (right) modified blades

Research on quality, shelf life and nutrient content of galip nuts

The project team undertook a series of experiments to understand shelf life, post-harvest handling and the nutritional values of galip nuts (Bai et al. 2017a, 2019a, 2019b, 2021). These experiments have had major impacts on the capacity of the emerging industry to produce *Canarium* nut products of high quality. Major changes observed as a result of research include:

- **Prolonged shelf life** – The nuts were usually sold and consumed fresh, with a shelf life of up to 72 hours from cracking. We experimented to find the best ways to dry or roast the nuts to prolong shelf life. The nuts can now have shelf life of up to 12 months under ambient conditions at 24° C when packed properly. Proper drying and roasting of nuts are now practised in the private sector.
- **Benefits of proper storage conditions** – Traditionally, nuts are stored in freezers. Our research showed that freezer storage decreased the nuts' shelf life and, therefore, should be avoided. The cracked nuts (kernels) can be safely stored at 25° C for up to 12 months (Bai et al. 2017b, 2019b).
- **Nutritional benefits** – We assessed the nutrient composition of *Canarium* compared with popular nuts including almond, cashew, pistachio and peanut. Our study suggested that *Canarium* can provide a wide range of mineral nutrients, such as iron and zinc (Bai et al. 2019a).

Testing the market for processed *Canarium* products

We developed and tested commercial business scenarios in the East New Britain and Port Moresby markets that could lead to sales at the local community level, the domestic market and niche export markets.

The principal approach involved developing an attractively designed product range, and targeting consumers shopping in premium supermarkets, and duty-free buyers, tourists and expatriates keen to buy something unique from PNG. Premium pricing with limited distribution was led by the development of purpose-designed consumer branding and a targeted promotional campaign directed at point of purchase. Key objectives were educating consumers and raising awareness of the features and benefits of a new food product, and where to taste and buy galip for the first time in PNG.

The outcome was the establishment of the Galip Nut Company brand as a practical vehicle for gaining consumer acceptance. This required the development of a range of great-tasting varieties, developing tightly managed product specifications for food safety, ensuring 12-month shelf life using premium oxygen-barrier packaging, and adding nutritional information and smart labelling using QR codes that directed users to a website for additional product information.

A range of galip nut products were developed and trialled for different retail outlets in East New Britain, including roasted, salted, testa-on and testa-off products. In 2018**,** a range of products with new packaging was developed specifically for formal markets in Port Moresby. Three main products were launched in the Port Moresby market including natural, roasted and peeled products. These were distributed in 3 CPL supermarkets and in Prouds Duty Free at Jacksons Airport, Port Moresby.

Figure 12-8: The Galip Nut Company product range developed for Port Moresby

Factory production

The demonstration processing factory applied all of the knowledge above to produce products for testing in formal markets. As a result of these interventions, factory production was greatly upscaled from less than one tonne of raw material (nut-in-pulp) purchased at the start of the project in 2014 to 207 tonnes in 2018. The factory provided direct income for over 1,300 smallholder farmers in 2018. Furthermore, the factory created opportunities for entrepreneurs to enter the supply chain, as agents collecting galip from farmers and in hiring trucks to transport galip to the factory (Table 12-1). In 2019, raw material was in short supply due to the entry of commercial galip processors and a poor nut-producing season (Table 12-1).

Table 12-1: The impact of the NARI demonstration processing factory on farmers in East New Britain during the project

Year	Tonnes of nut-in-pulp purchased by the factory	No. of farmers selling to the factory	Farm-gate value based on PGK1.0–1.5/kg	
			PGK	US$
2014	Small volumes (<1000 kg) for research trials	N/A	N/A	
2015	11	243 smallholder farmers	10,669	2,874
2016	25	647 smallholder farmers	26,349	7,099
2017	65	659 farmers recorded (many others not captured) 544 farmers selling at factory gate, 115 selling on farms Women selling direct and entrepreneurs collecting from farmers and selling to factory	65,000 at farm gate	17,513
2018	207	1,349 farmers recorded (many others not captured) 44 purchases at farm gate and 1,305 at factory door Women selling direct and entrepreneurs collecting from farmers and selling to factory	310,500 at factory gate	83,659

Before the COVID-19 pandemic, market testing had proven sales demand exceeded supply. Products were often out of stock and the factory was unable to supply the markets in Port Moresby. Total revenue from the sale of all products including kernel, cake, oil, and shells in 2018–2019 was PGK246,222 (US$66,340).

Figure 12-9: Left to right: Professor Helen Wallace, Simiama Ling-Kapi and Tio Nevenimo launching the Galip Nut Company product range in a CPL supermarket

Financial analysis of the demonstration processing factory

Financial analysis has informed operational and strategic decisions at all stages of the project. An early observation was that the purchase of the fruit contributed 49% of the total cost of the final product in 2017, due to the costs of sending the project team to the villages to purchase the raw material at PGK1.00 per kg. A cost–benefit analysis determined that it would be more cost-effective to offer a higher purchase price (PGK1.5 per kg) at the factory gate. This led to the dual pricing strategy, which largely replaced farm-gate purchasing with factory-gate purchasing, and reduced the ex-factory product cost of dried testa-off kernels by 31% per kg.

The financial analysis produced a detailed and accurate gross-margin analysis, concentrating on the variable costs of processing across various product lines. Gross margin indicates how much profit a company makes after paying the cost of the goods sold. It is a measure of the efficiency of a company using its raw materials and labour during the production process, which made it a more appropriate approach for the project's first phase.

In 2018, the project launched its main product line and made substantial sales to retailers. The ex-factory average variable cost of producing one kg of packaged natural or roasted kernel (testa on, dry, 2% moisture content) was PGK55.63 (US$14.99) and the peeled kernel (testa off, dry, 2% moisture content) was PGK74.02 (US$19.94). The analysis allowed a costing breakdown of the different stages. For example, for the peeled product, PGK29.37 (US$7.91) related to the purchase of the fruit, PGK8.05 (US$2.17) to de-pulping, PGK9.56 (US$2.58) to cracking, PGK5.20 (US$1.40) to testa removal, PGK7.41 (US$2.00) to drying, sorting and packing, PGK1.92 (US$0.52) to electricity, PGK0.18 (US$0.048) to diesel, and PGK12.34 (US$3.32) to overheads.

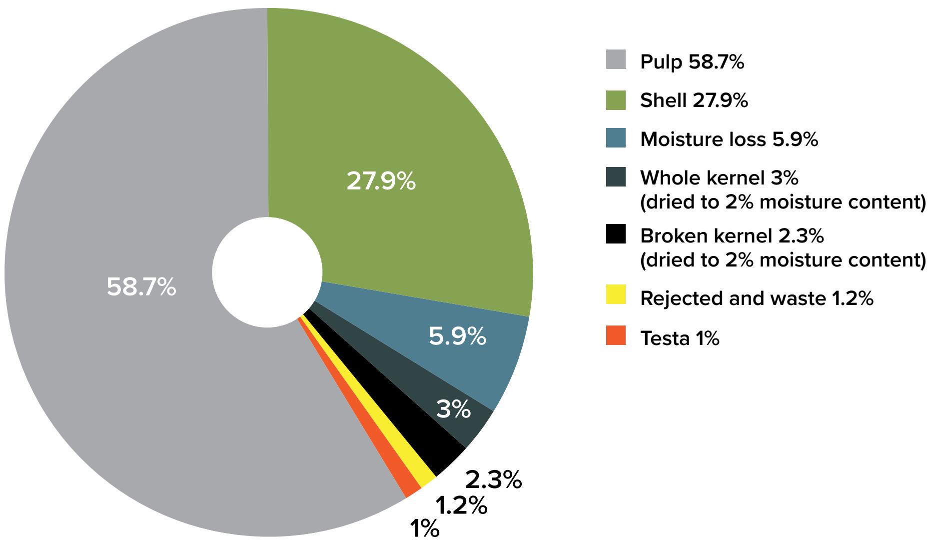

Figure 12-10: The components of galip fruit (by percentage)

Between January and December 2018, the factory made 248 unique sales totalling 1,241 kg. Among the nut sales, the vast majority (84%) was to retailers in Port Moresby with the remainder to a combination of private and retail purchasers in Kokopo, Keravat, Lae and Rabaul. The gross profit margin was 39.5%.

On the supply side, farmers are motivated to collect and sell at the prices offered for fruit. On the demand side, the factory is gaining repeat orders at premium prices with reasonable gross profit margins. Looking forward, there is considerable scope to reduce costs as our production process matures and becomes more efficient, and we develop new product lines that take advantage of the lower average costs of the mechanised production process and expand domestic and international sales.

Figure 12-11: Dalsie Hannett with the Galip Nut Company product range for which she is responsible

Figure 12-12: Women selling galip nuts from Vunamarita Island, East New Britain, to the factory.

Credit: Emma Kill

The emerging private *Canarium* industry

In 2019, there were 4 active *Canarium* processors sourcing their own nuts and establishing their own markets, with an estimated farm-gate value of PGK300,000–PGK400,000 (US$80,830–US$107,773). One processor was operating from the demonstration factory in a public–private arrangement with NARI. The other 3 were operating in their own facilities. All of these operators have received technical support and advice from the project.

In 2022, there were 2 active processors, with one supplying retail markets in Port Moresby. This indicates a transition to private sector processing and is very positive for the industry. The other processor is positioning for export and is engaged in a public–private partnership with NARI in the demonstration factory. The project team continues to provide advice and support on processing methods, equipment, markets, packaging, and product quality and storage for both processors.

The project has also produced factory-operating procedures and technical information for *Canarium indicum* nut processing for Indonesian farmers. FairFlavor, a food technology start-up is producing non-dairy, alt-protein products from *Canarium indicum* nuts, known as kenari nuts in Indonesia.

We have also developed a website – www.galipnuts.net – to inform consumers about galip's nutritional and community benefits.

Figure 12-13: **Galip nut products produced by Devine Management Systems and Nuigini Organics for sale in retail outlets**

Figure 12-14: Galip products presented at the launch in East New Britain in 2018

Figure 12-15: Galip team members launching galip products in Port Moresby in 2018

Figure 12-16: Dorothy Luana from the Galip Club showcasing her galip product at the launch, 2018

Box 12-1: **Lessons for creating a new industry**

These projects have demonstrated the potential of an industry based on *Canarium* nut processing to improve livelihoods of smallholders in PNG, and produced some key lessons on creating a new industry:

- It is essential to build the confidence of the private sector to invest. There was little investment at the start of our project as the private sector were unsure if an industry based on *Canarium* nut products was viable. Once strong market demand had been demonstrated, smallholders, microenterprises, entrepreneurs and SMEs began to invest as they had gained more confidence in the industry.
- Engaging strongly with the private sector through the value chain, to understand their needs and challenges, was a critical success factor.
- Long-term donor support was needed to reduce risk by, for example, finding solutions to technical problems and trialling many things that did not work.
- A range of technical solutions tailored to each of the stakeholders was needed, rather than a simple 'one size fits all'.

Our project team's transdisciplinary approach was a strength, as the researchers could adapt to constantly evolving challenges. In particular, strong focus on markets and consumers, coupled with close engagement with the private sector, produced economic benefits to smallholders and processors. The scientific approach enabled many breakthroughs in processing methods and equipment, and the social research produced strong outreach and impact by engaging and partnering with smallholders and SMEs. The emerging *Canarium* industry now needs to scale up to expand into export markets in the next phase of its development.

Case study: The economic impact of factory sales for female smallholders

Many women are making small regular sales to the NARI demonstration processing factory, which is having a positive ripple effect on their lives, as these examples show:

- A widow with 7 children is earning additional income to support her family.
- A young mother of 3 sold about 155 kg of nut-in-pulp and was able to support her children financially during a difficult time.
- A teenage girl of 15 sold galip during the school holidays and earned enough to pay for her new school uniforms.
- A young mother of 3 was selling galip to buy basics for the family and buy medication for her sick child.

Figure 12-17: A mother and child deliver galip nuts to the factory.
Credit: Theo Simos

Before the development of the galip industry and large-scale purchasing by downstream processors, collecting, cracking and trading of *Canarium* nuts was the domain of women and children.

Data gathered for the project at the point of sale for smallholder farmers suggested that more women were selling to the factory when the purchases were made at the farm gate, than when they had to take their produce to the factory door. This could indicate that women are facing more difficulties in transporting their product to the factory and/or that men are taking control of the galip monies now that it is moving beyond the informal economy. While there is still some conjecture about the gendered division of labour among rural smallholder families in PNG (Mikhailovich et al. 2016), it is generally understood that men traditionally work on the commodity crops, such as cocoa and copra, while women are mainly involved in the informal markets, such as betel nut (Cahn and Liu 2008). This raises further research opportunities to create best practice purchasing systems, which would most benefit the work of women and children, rather than commoditise and remove what is an important part of their informal economy.

Surveys of smallholders participating in the galip industry indicate that money is also used for food, clothes and school fees. The survey found that between 70% and 90% of smallholders will save some of the money made from selling galip. The willingness of rural people to supply galip nuts via both marketing pathways indicates that the perceived rewards outweigh the costs in time and cash expenditure.

References

Bai SH, Trueman SJ, Nevenimo T, Hannet G, Bapiwai P, Poienou M and Wallace HM (2017a) 'Effects of shade-tree species and spacing on soil and leaf nutrient concentrations in cocoa plantations at 8 years after establishment', *Agriculture, Ecosystems & Environment*, 246:134–143.

Bai SH, Darby I, Nevenimo T, Hannet G, Hannet D, Poienou M, Grant E, Brooks P, Walton D and Randall B (2017b) 'Effects of roasting on kernel peroxide value, free fatty acid, fatty acid composition and crude protein content', *PloS one*, 12(9):e0184279.

Bai SH, Brooks P, Gama R, Nevenimo T, Hannet G, Hannet D, Randall B, Walton D, Grant E and Wallace HM (2019a) 'Nutritional quality of almond, canarium, cashew and pistachio and their oil photooxidative stability', *Journal of Food Science and Technology*, 56(2):792–798.

Bai SH, Nevenimo T, Hannet G, Hannet D. Jones K, Trueman SJ, Grant EL, Walton DA, Randall B and Wallace HM (2019b) 'Freezing, roasting and salt dipping impacts on peroxide value, free fatty acid and fatty acid composition of nut kernels', *Acta Horticulturae*, 1256: 71–75.

Bai SH, Hannet D, Hannet G, Grant E, Komolong B, Jones K and Wallace HM (6 October 2021) 'Effects of fruit depulping on kernel quality of *Canarium indicum*', *Acta Horticulturae*, 1340:145–148.

Cahn M and Liu M (2008) 'Women and rural livelihood training: a case study from Papua New Guinea', *Gender and Development*, 16:133–146.

Gama T, Wallace HM, Trueman SJ and Hosseini-Bai S (2018) 'Quality and shelf life of tree nuts: A review', *Scientia Horticulturae*, 242:116–126.

Matthews PJ and Gosden C (1997) 'Plant remains from waterlogged sites in the Arawe Islands, West New Britain province, Papua New Guinea: implications for the history of plant use and domestication', *Economic Botany*, 51:121–133.

Mikhailovich K, Pamphilon B, Chambers B, Simeon L and Zapata JR (2016) 'Exploring the lives of women smallholder farmers in Papua New Guinea through a collaborative mixed methods approach', *Cogent Social Sciences*, 2:1.

Nevenimo T, Johnston M, Binifa J, Gwabu C, Angen J, Moxon J and Leakey R (2008) 'Domestication potential and marketing of Canarium indicum nuts in the pacific: producer and consumer surveys in Papua New Guinea (East New Britain)', *Forests, Trees and Livelihoods*, 18:253–269.

Wallace HM, Poienou M, Randall B and Moxon J (2010) 'Postharvest cracking and testa removal methods for Canarium indicum nuts in the Pacific', *Acta Horticulturae*, 880:155–159.

Wallace H, Randall B, Grant E, Jones K, Walton D, Poienou M, Nevenimo T, Moxon J and Pauku R (2016) 'Processing methods for Canarium nuts in the Pacific', *Acta Horticulturae*, 1128:145–149.

Wallace HM, Hannet D, Hannet G, Hosseini-Bai S, Jones K and Komolong B (2022) 'Commercialising an indigenous agroforestry tree: overview of commercial processing methods for *Canarium indicum* (galip) nuts in Papua New Guinea', *Acta Horticulturae*, 1355:345–350.

Walton D, Randall B. Poienou M, Nevenimo T, Moxon J and Wallace H (2017) 'Shelf life of tropical Canarium nut stored under ambient conditions', *Horticulturae*, 3(1):24.

Chapter 13

Experiences of the Master TreeGrower training program in Australia, Africa, Asia and the Pacific

Rowan Reid

Abstract

An outreach initiative of The University of Melbourne, the Master TreeGrower (MTG) course aimed to extend the knowledge and support networks of Australian farmers on tree growing. Since 1996, more than 120 MTG courses have been run across Australia for more than 2,500 landholders. In 2010, the MTG program was transferred from The University of Melbourne to a specially created not-for-profit organisation, the Australian Agroforestry Foundation, and paired with the Peer Group Mentoring (PGM) model developed by the Otway Agroforestry Network. With the PGM model, graduates of the MTG course are trained and then paid to mentor other landholders in designing and developing their own agroforestry projects.

Partnering with ACIAR and others, the Australian Agroforestry Foundation extended the MTG program to developing countries, with 12 MTG courses delivered in Africa, 10 in Indonesia and 4 in Vanuatu, to more than 1,000 landholders in total. Most participants were enthusiastic about the course, and many were keen to share their experience and knowledge with others in their communities. Less certain is the extent to which the course leads to long-term practice change, such as a farmer becoming more involved in establishing and managing trees. Our observations suggest that this depends on the farmer’s degree of involvement in a regional farmer group and ongoing support from non-government organisations (NGOs), government agencies and industry groups.

As part of the Indonesian project, a PGM training workshop was conducted in Semarang and Ungaran in July 2018 with 8 potential mentors from Bulukumba, Pati and Gunungkidul. The team adopted the term ‘farmer-2-farmer mentoring’ and produced a mentoring action plan to support the 8 participants in mentoring other farmers. The action plan was used to monitor the progress and to evaluate the effectiveness of the farmer-to-farmer mentoring. Monitoring data were collected and the final evaluation subsequently confirmed that the technique holds potential, but requires local leadership and support.

In this chapter, I review the development of the Australian MTG program and the PGM model, highlighting the underlining extension philosophy, the key educational and training components, and how these components are adapted to each local situation.

Acknowledgements

I would like to acknowledge the many hundreds of individuals, NGOs, industry members and government agencies that have contributed to the development of the Australian Master TreeGrower and Peer Group Mentoring programs over the past 20 years. This includes landholders, tree growers, extension agents, nursery owners, contractors, sawmillers, extension agents and government officers, and the many regional, state and federal government agencies or community and industry organisations they may work for.

The program could not have been established in Australia without the financial support of the Myer Foundation, the Joint Venture Agroforestry Program, Land and Water Australia, The University of Melbourne and many Australian Government programs supporting landcare and forestry. More recently, our international programs have been strongly supported by ACIAR, Beyond Subsistence, The Crawford Fund, WithOneSeed and many private donors.

Definitions are the foundation of extension

In developing the Australian MTG program and the PGM model, my objective was to help drive agroforestry development in a way that reflects the aspirations and interests of the farming community: 'Agroforestry should look and feel like forestry by farmers for farmers, and should reflect the diversity of interests, resources and aspirations of the farming community' (Reid 2008:7).

With this objective, the MTG and PGM program set out to assist farmers determine how, and in what form, their participation in tree growing could provide real and sustainable improvements in their own quality of life. The degree to which the outcomes would meet the needs or interests of a particular industry, government agency or conservation group would seem to largely depend on:

- the extent to which there are shared goals, capacity and willingness among farmers to act
- adequate rewards for those farmers who provide the services or products sought by others
- the degree to which penalties are imposed on landholders for any negative externalities (for example, excessive weed growth, ongoing soil erosion, poor animal welfare outcomes).

The Master TreeGrower course

While every Australian MTG course is different, they all follow a similar framework (Table 13-1). This ensures a level of consistency and uniformity across the courses while allowing local stakeholders and participants to adapt the content to suit their own interests and requirements. The participants are mostly landholders with some experience in growing or managing trees, but may also include service providers such as nursery owners, contractors or consultants, government extension agents and industry members.

The MTG course runs over 6 to 8 days. After the personal introductions, during which participants share their interests and aspirations for tree growing, the course explores market opportunities and product specifications, then works backwards, through the marketing and processing options, tree and forest measurement and the silvicultural management of trees, to the design and evaluation of multipurpose projects that are best suited to each farmer. The final day includes a review of the program, participant evaluation and discussion on future activities, including peer mentoring.

The choice of the term 'master' was deliberate in that the program supports landholders as they face the challenge of deciding what type of trees to grow, for what purpose, and what establishment and management options would be most appropriate. The course title also infers that it is the landholder that must ultimately accept responsibility for their decisions.

In their review of several farm forestry extension and education programs in Australia, Bauer and Gordon (2003) reported that the Australian MTG course had caused 4 types of change to the businesses of participants and the sector generally:

- an increase in the number of trees planted
- an increase in the adoption rates of productivity
- an increase in the use of technology among MTG graduates
- the transfer of agroforestry technology from MTG graduates to other agroforesters by example and other knowledge transfer – the 'echo effect'
- changes in the reasons why farmers plant trees.

Table 13-1: The 5-part Master TreeGrower course framework

Photos are from the MTG courses held in Vanuatu and Indonesia.

1: Mastering the art of tree growing • Importance of farmers' decision-making and appropriate design. • Identifying farmers' perceived problems and aspirations (short, medium, long term).	
2: Markets for farm forest products and services • Identifying industry, community and government interests in trees on farms and their willingness to reward or support farmers. • Product and service specifications, marketing options, regulations. • Processing and marketing visits. • Secondary and on-farm markets for forest products.	
3: Measuring trees and forests on farms • Assessing trees and stands relative to product specifications and landholder needs and aspirations. • Documenting forest growth for timber, carbon and other values.	
4: Managing trees and forests on farms • Tree and forest growth, silvicultural options (e.g. pruning, thinning). • Examples of farmers applying silvicultural methods.	
5: Farm visits, graduation and the future • Appropriate design, risk assessment, evaluation of options. • Presentation of certificates. • Role of farmer groups and information networks.	

Since 1999, the MTG program coordinators have engaged social scientists to help them evaluate and guide program delivery and evaluation. One such team, led by a senior anthropologist from The University of Melbourne, concluded that:

> [the program was] stimulating the active involvement of farmers in the establishment, management and marketing of trees and forest products; encouraging enhanced landholder participation in regional and national farm forestry research and extension; and developing and implementing a course delivery model that satisfies participants' needs. (O'Meara and Wright 1999)

During 2008 and 2009 another anthropologist working on the program interviewed 250 past Australian MTG participants (16% of all participants at that time) to seek feedback on their experience and some indication of how their participation had influenced their involvement in agroforestry (Reid and Deans 2009). Most respondents highlighted multiple reasons for growing trees, reflecting the strong emphasis within the MTG on multipurpose agroforestry design and management as a means of capturing a range of opportunities and reducing risk. Reid and Deans (2009) suggest that this is one of several features of the program that distinguish it from other forestry and revegetation extension initiatives, which tend to focus on either the environmental or commercial aspects of tree growing.

Reid and Deans (2009) concluded:

> The MTG program is an outstanding example of extension. MTG participants enthusiastically support the program, increase vegetation planted on their own land after completing the course, are more inclined to plant vegetation for public good and relate to trees and vegetation inside a complex matrix of social, ecological and economic purposes.

The Peer Group Mentor program

Noticing how farmers in their region valued the leadership and advice of those who had completed the local MTG courses, the Otway Agroforestry Network began to explore the concept of enhancing and facilitating farmer-to-farmer extension (Curry and Reid 2009). The proposal was to train, then pay, experienced local tree growers to act as mentors, supporting and assisting other landholders as they set about designing and managing their own agroforestry projects.

During the initial training, the mentors themselves set down what they considered to be the attributes of an effective peer group mentor. They determined that a peer mentor does not need to be an expert in any aspect of tree growing. Rather, what they bring to the program is their experience and credibility as a local tree grower, their knowledge and involvement in local tree-growing information networks and their commitment to their region. They understood that what is appropriate for one landholder might not suit another and that people differ in the type of support and mentoring they need. A good mentor, they determined, ought to have:

- skills in communication and interpretation so that they can 'read' both the people and the physical, social and economic landscape in which they work
- the ability to seek out information and expertise appropriate to the situation
- a desire to help and support other landholders achieve success in their projects
- some practical experience and credibility as a tree grower within their local community
- a willingness to share their experience and knowledge with others.

The critical starting point is for the mentors to meet the landholder(s) on the latter's property with a view to understanding their interests, needs and aspirations, and give them with a realistic picture of what can be done. Other types of activities identified by the Otway Agroforestry Network (Curry and Reid 2009) as appropriate for mentors included:

- hosting a tour of the mentor's own property
- taking the client to another farm or forest that they believe might be relevant to their needs or interests
- preparing tree orders or facilitating contractors
- working directly with the landholder on the project (for example, setting out fence lines, planting, pruning)
- doing follow-up research on behalf of the landholder
- assisting with funding applications or arranging meetings with industry, government or other potential partners
- establishing or conducting ongoing monitoring (for example, photo points, growth measurements)
- encouraging landholders to attend group activities
- assisting in organising and presenting local farm walks, seminars or other group activities.

To date, the Otway Agroforestry Network has trained more than 30 landholders to act as mentors and run more than 100 PGM site visits. With government support, it has helped other communities trial the PGM model in Australia, including in the southwest of Western Australia and the New England Tablelands of New South Wales. Despite initial interest and enthusiasm for the PGM trials, none of these other regions have kept their PGM programs going.

International application of the MTG and PGM programs

In response to international interest in the MTG model, the Australian Agroforestry Foundation teamed up with several partner organisations to deliver MTG courses across Africa, Southeast Asia and the Pacific region. The aim was to ensure that each course followed the MTG framework (Table 13-1) and conformed to the philosophy of the program. Naturally, the content varied to reflect local conditions, farming systems, local forest values and product markets, and the interests of participants and partners. Participants were either personally invited to attend because of their involvement in farmer groups or self-selected in direct response to public notification. The method of evaluation and the range of data collected also varied.

Africa

The first MTG course to be conducted outside Australia was delivered over 5 days in Kabale, Uganda, in 2013, as a partnership between the Australian Agroforestry Foundation, Beyond Subsistence (an Australian NGO), the World Agroforestry Centre (Uganda) and the local community. In many respects, the Kabale course was very similar to the MTG courses run in Australia. Mornings were spent in the classroom and afternoons were spent in the field, often on participants' farms. Presenters ranged from experts to local practitioners. There was plenty of time for discussion and debate. The participants included 42 farmers (40% female), 24 local or regional professionals working with NGOs, government or educational intuitions, and 9 African observers. Nine Australians were involved as presenters, mentors and observers. The content covered all the aspects of the framework (Table 13-1).

Notable differences were the large class size (most Australian courses have about 20 participants), the delivery over consecutive days and the need for translation.

On the final evening of the course, participants were invited to complete an evaluation form. The one-page questionnaire asked them to rate, then comment on, the value and relevance of the presentations, field trips, venue and food, and the value of the program for themselves and their communities. These participant quotes highlight the perceived value of the course and provide some insight into the constraints affecting agroforestry development in the region:

> Loaded with valuable info about eco system, conservation and tree growing and management for eco gains.
>
> — MTG participant, Kabale, Uganda

> Lovely, professional, educative, inspiring, focused & motivating. Selfishness can't lead us anywhere based on Australian sharing.
>
> — MTG participant, Kabale, Uganda

Participants were invited to rate (on a 5-point Likert scale) the value of the presentations and field trips and the value of the MTG to the wider community, all of which rated very highly (Figure 13-1).

On the final day of the Kabale course, participants discussed the need for a local information and support network for farmers interested in growing and managing trees. With broad support for the idea of creating a Kabale Agroforestry Network, the group formed a steering committee with similar aims and objectives to that of the Otway Agroforestry Network.

Early in the following year of 2014, Beyond Subsistence delivered a MTG course in Niger for 27 participants. The course was conducted in the Maradi region where trees are seen as having potential to control soil erosion, enhance crop production through nutrient enhancement, supplement fodder reserves, contribute to household needs, and provide income through the sale of firewood and poles. Participants were selected as key people who were likely to share what they learned with their networks and help run future courses and demonstrations.

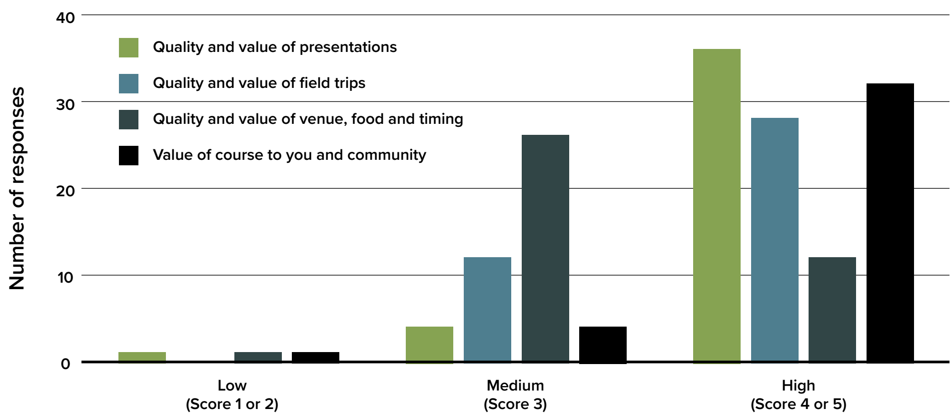

Figure 13-1: **Participants' responses when asked to rate (on a 5-point Likert scale) the quality and value of components of the Master TreeGrower course held in Kabale, Uganda (n = 41)**

Oral evaluation reports (written reports were not possible due to poor literacy and language issues) showed that participants were keen to encourage their communities to take a leadership role in dealing with factors that they felt were hindering agroforestry adoption, such as unrestricted grazing of goats and stealing. In 2015, the participants themselves ran a second MTG course in Niger.

A follow-up MTG course was run in Ntungamo, Uganda, in 2014 for 50 participants from 4 districts. The Ntungamo course focused on the many roles trees on farms can play in supporting livelihoods, such as providing firewood, enhancing wetlands and increasing biodiversity values (Beyond Subsistence 2014). As in Kabale, on the final day of the course the participants decided to support the formation of a local agroforestry network for farmers interested in growing and managing trees on their farms (Beyond Subsistence 2014):

> The African potential can only be realised once farmers understand the dual opportunities that trees can play in not only providing environmental benefits, but also providing economic benefits.
>
> — MTG participant, Ntungamo, Uganda

Since 2014, Beyond Subsistence has delivered a further 8 MTG courses in Africa across 4 countries (Uganda, Niger, Zimbabwe and Ethiopia). MTG impact stories collected by Beyond Subsistence after the course seem to represent the most powerful outcome of evaluations undertaken. An example case study is presented here.

Case study: The Master TreeGrower course empowering women in Uganda

Story by Beyond Subsistence

Margrate is a widow with 2 children who attended our 2016 MTG course in Wakiso, Uganda. Prior to the course her main income was derived from farming coffee and plantain. She also reared goats, pigs, chickens and rabbits and had a small tree plantation.

After completing the MTG course, Margrate realised the value of pruning and thinning trees. She took it upon herself to begin offering these services to other farmers. She began confidently harvesting her own plantation and used the timber to put a new roof on her home and create an animal pen, saving herself significant expense.

Margrate then decided to plant a greater variety of trees on her small farm, including grevillia, pine, mango, guava, jackfruit and avocado. These new plantings have provided her with valuable fruits and future timber.

From the MTG program, Margrate learnt the value of growing herbs (particularly medicinal ones) and vegetables around her home. Using pots and bags in creative ways, Margrate has planted a range of species that provide her family with year-round nutritional vegetables and herbs. Impressively, she has invested in some equipment, such that she now value-adds these herbs and sells them as oils or dry matter in the local markets. She is teaching her new-found skills to other local women in the community. Margrate can now confidently provide for her family and generate additional income for the future.

Indonesia

During the first phase of ACIAR project FST/2015/040, 'Enhancing community-based commercial forestry in Indonesia', it was identified that Indonesian smallholders generally lack knowledge of the market value and product specifications for timber, and lack the skills required to manage their trees to improve timber quality and value (Reid et al. 2014). In particular, there was:

- a lack of understanding about how the local forestry market operated, such as the demand for different products, their specifications (grades, log length), scope for alternative products and strategies in the marketplace
- limited knowledge of how to measure and describe the volume and quality of trees and timber, assess stocking rate, and describe forest attributes such as mean diameter, basal area and competition levels
- poor understanding about how smallholders can guide and influence the growth and development of their forests through choices of species and germplasm, planting configuration, pruning, thinning, and harvesting strategies.

To address these knowledge shortfalls, the research team chose to design a flexible, participatory learning model based on the Australian MTG program that could be delivered as a short course for groups of farmers in their regions. Following a training workshop, the first Indonesian MTG course was delivered to a group of farmers in the Gunungkidul region in March 2014. This was followed by courses in Pati, Sumbawa, Bulukumba and Konawe Selatan.

All up, 145 people participated in the 7 regional courses. The majority (81%) were farmers and, of these, 11% were female (Reid et al. 2014). Local government extension agents and local partners selected the participants based on their interest in the project, their tree-growing activities and their involvement with local farmer groups. The non-farmers (18%) included government extension agents, forest officers, industry members and NGO representatives. While the content was necessarily adapted to suit local conditions, all the courses strongly emphasised the core elements of markets, measurement and management (Reid et al. 2014).

Figure 13-2: Women celebrate their completion of a MTG course in Indonesia.

On the final day of each course, the participants were asked to complete a written survey that included 5-point Likert scale questions and the opportunity to comment on the course content and value. Participants were asked to rate the degree to which their participation in the course had improved their knowledge.

When asked to nominate the 3 most significant experiences or learnings from the course, more than 20% of the responses (70 of 327) were directly related to the marketing of products; for example:

> Knowing good and bad wood
>
> — Farmer participant in the MTG course at Gunungkidul

> Plant a tree based on market demand
>
> — Participant in the MTG course at Malleleng, Bulukumba

Similarly, 35% (114 of 327) of the responses related directly to silvicultural management, making it the most highly rated topic, with quotes such as:

> Know the benefits of thinning and pruning
>
> — Farmer participant in the MTG course at Bulukumba

> Knowing how to improve the quality of the wood in the maintenance of plants / trees (pruning and thinning)
>
> — Farmer participant in the MTG course at Konawe

Participants in the Indonesian courses were similarly interested and enthusiastic about sharing their knowledge. Overall, 44 of the 145 participants (30%) expressed an intention to share their knowledge or provide leadership on community-based commercial forestry within their community (Reid et al. 2014):

> Will transmit experience to other farmers
>
> — Farmer participant in the MTG course at Gunungkidul

> Practice on own land so that it becomes an example for the people around
>
> — Farmer participant in the MTG course at Konawe

A redesigned second series of courses in Indonesia

Based on a national review of the first series of courses, the regional teams were encouraged to adapt the MTG model to better suit their own region and a second series was conducted in 2018 with 15 MTG courses delivered at the 5 project sites (Pati, Gunungkidul, Bulukumba, Buolemo and Lampung).

The second series of courses was evaluated using a pre-test conducted on the first day of each MTG course and a post-test conducted on the last day of the course (Muktasam et al. 2019). Participants' ideas, suggestions and comments about the course were also obtained during this evaluation. A few months after the initial evaluation, Muktasam et al. conducted a series of additional focus group discussions, observations and in-depth interviews (unpublished).

A total of 298 participants were involved in the 15 MTG redesigned courses, consisting of 71% male and 29% female adults. According to their self-stated occupations, 75% of participants were farmers and 25% were non-farmers, such as those working at home, village staff, private sector staff and civil servants or government staff (Muktasam et al. 2019).

These participants claimed that they had gained significant knowledge and skills on the topics of:

- tree management – pruning and thinning (62%)
- tree establishment on farms (51%)
- measurement of trees and logs (47%)
- tree species selection and genetic quality (47%).

The participants further claimed that they had learnt about the use of trees for other benefits and timber market opportunities. Most importantly, the evaluation found that a high proportion of participants expressed a willingness to change their existing farm management practices by implementing their knowledge on:

- pruning trees (54%)
- measuring trees (51%)
- growing trees on their land (46%)
- thinning (40%).

Other participants expressed their willingness to grow (more) trees, to share their learning with other farmers and encourage farmers to work in groups. In addition, most participants asserted that all the equipment and tools used and shared in the course (such as the measurement tape and pruning gauge, which they were free to keep) were useful and would support them in future. Finally, the participants suggested that future MTG courses should include more women participants and that the course should be longer.

Muktasam et al. (2019) concluded that the redesigned MTG courses were effective in promoting learning and changes in smallholders' farm management practices. Almost all participants in the courses expressed a desire to implement their knowledge and skills in managing their trees and farms for better outcomes.

Figure 13-3: Farmers participating in a Master TreeGrower course in Indonesia learn how to measure trees in the field.

Timor-Leste

The first Timor-Leste MTG course was delivered in late 2014 in partnership with an Australian NGO, WithOneSeed, in the Baguia region in the central highlands. WithOneSeed has a team of local staff that run several local nurseries, providing advice and support to local farmers about tree establishment and management. They reward those farmers who grow trees successfully and they collect data on tree survival and growth with a view to linking farmers into the international carbon market. This team helped design and deliver a 5-day MTG program for more than 40 local farmers, which included:

- a review of their motivations for growing trees
- the potential for trees to provide products and services that they could use or sell into local, domestic or international markets
- tree measurement for timber and carbon
- possible species, nursery propagation, establishment and management options suited to the area
- an exploration of their ideas about how they would apply the knowledge and skills they had gained.

Most of the feedback from participants centred on improving the prospects for future generations, although one younger farmer said the knowledge he gained was important for his own future.

Translated written responses from the participants (Andrew Mahar, personal communication, 2015) highlight how the MTG course could be adapted to reflect local farmers' needs and aspirations:

> Got an excellent understanding of tree pruning
>
> Helped me be a better farmer
>
> Increased and improved our knowledge
>
> Support our existence

And, like MTG course participants in Australia and other countries, the Timor-Leste participants could see how the program might contribute to their community in the future:

> Most important for increasing our capacity in the future
>
> Important for me, my family and the future
>
> Added value to the community

WithOneSeed staff reported that the MTG course had made a significant contribution to the development of forestry on farms within the Baguia community. We are now exploring the possibility of the Baguia community acting as mentors to lead MTG courses in partnership with the Australian Agroforestry Foundation in other regions of Timor-Leste. Andrew Mahar, the WithOneSeed project director, later wrote: 'The MTG course is well targeted, clear and responsive, addressing the needs of the community over a five-day period. The program is delivered by people with not only academic backgrounds but, significantly, they are also practitioners (tree farmers) in their own right. The subsistence farmers in the community of Baguia gained significant knowledge and practical hands-on experience that they are now putting into practice.' (Andrew Mahar, personal communication, 2015).

In 2019, a second MTG course was conducted in Baguia, with strong leadership shown by the WithOneSeed staff and some of those who had participated in the first course. We then travelled to Suai on the southern coast of Timor-Leste where a third MTG course was delivered. Both courses enjoyed strong community support and engagement.

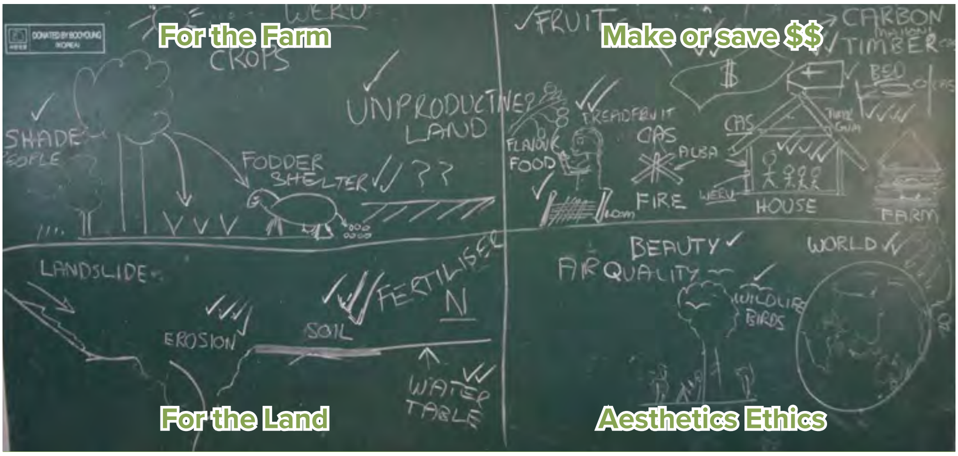

Figure 13-4: **Summary of MTG farmer participants' discussion about tree values and products, Timor-Leste**

Figure 13-5: **Rowan Reid leading discussion with MTG participants in Suai, Timor-Leste**

Vanuatu

ACIAR project FST/2016/154 ‘Enhancing returns from high-value agroforestry species in Vanuatu’ (2017–2022) included a review of the extension program in forestry. The review highlighted gaps in the support and education provided to landholders to help them review, design and implement forestry options that meet their particular needs and aspirations. For farmers interested in generating income by selling tree products and services, there was little information about market specifications, prices and how to get their products to the buyers.

The project then supported the adaptation of a series of MTG courses – both the design and delivery – across Vanuatu between 2018 and 2020. To initiate the project, a 3-day MTG pilot workshop was conducted at Farea Pasifika (Pasifika House) in Port Vila in June 2018, with 26 participants, including farmers and representatives from private companies, NGOs, government departments and educational institutions.

Workshop participants strongly endorsed the 5-part MTG framework (Table 13-1). They saw how the course content could be adapted to suit the wide range of farmers’ interests in tree growing – including the interests of women – and the various market opportunities, including growing whitewood and mahogany for sawn timber, sandalwood for essential oils, and *Canarium* for nuts. There was also strong support for providing participants with a MTG hat, diameter tape, certificate and sign.

The first full Vanuatu MTG course was then conducted for a group of Ni Vanuatu women at the Avunatari Mission on Malo in October 2018. Of the 18 participants, 14 were from Malo women’s group and 4 were from BBB (Bisnis Blong Buluk) women’s group. The 8 trainers were from Vanuatu and Australia. An unpublished evaluation survey conducted by the ACIAR project team interviewed the 18 participants. While most of the findings were positive, particularly with reference to the involvement of women as trainers, participants stressed the importance of teaching materials being made available in the local language.

The next MTG course in Vanuatu was coordinated by staff from the Vanuatu Department of Forests (DoF). They selected more than 20 local farmers to participate in the 4-day course. On the first day of the course, participants shared a diverse range of reasons for wanting to grow trees, which spanned the 4 themes of:

- supporting agriculture
- conserving soil, water and biodiversity
- producing tree products
- aesthetic or community reasons.

There was discussion about how producing timber on farms can provide secondary benefits, other than the prospect of selling timber. The following days included a review of potential timber species for farm planting, a visit to a local sawmill and timber research facility, and exercises in measuring and managing trees on farms.

On the final day, the local DoF staff invited all the participants to say what they would do now, having done the MTG course, and what ongoing support they needed. The farmers emphasised their need for seedlings, assistance with establishing the trees, access to markets, and ongoing information and tools. The DoF was seen as the potential provider of these needs – possibly reflecting a history of DoF handouts to farmers. When presented with the example of the Otway Agroforestry Network where farmers support each other through a peer support group, some of the older farmers led discussion about the formation of a Santo forestry group.

Figure 13-6: **An all-women Master TreeGrower course was run on the island of Malo, Vanuatu.**

For the third and final Vanuatu MTG course, participants were invited from across the country based on their experience as sandalwood growers or industry members. More than 30 growers and several contractors, sandalwood buyers and employees of larger growers attended. Many participants expressed a diverse range of reasons for wanting to grow trees other than money, and many had an interest in other timber species.

There was much discussion about the community benefits for small-scale forestry in Vanuatu with respect to education, community engagement and industry development. Their recognition of these values highlights some of the extended benefits that can arise from involving the farming community in forestry development. Over the next 4 days, the course included inspections of sandalwood plantations on both small and large farms, and visits to exporters and processors of sandalwood timber and oil, sandalwood research sites and a nursery.

This course exposed the depth of experience and knowledge within the community about growing sandalwood and highlighted the importance of developing networks to share this experience for the benefit of the wider community.

Figure 13-7: Participants discuss the planting of trees in food gardens, Vanuatu.

Enduring impacts of the MTG courses

At this early stage, it is difficult to demonstrate that farmer participation in a MTG course has had a direct impact on the adoption of agroforestry practices by individuals or their communities. However, anecdotal evidence suggests that the courses have led to increased agroforestry-related activities and greater participation of farmers in agroforestry extension within their communities.

In Uganda, the course has led to the formation of at least 2 agroforestry networks (at Kabale and Ntungamo); direct involvement of participants from the Kabale MTG course in the delivery of the Ntungamo MTG course; a number of junior landcare projects in local schools, which include growing vegetables and planting trees; and the establishment of new agroforestry-related businesses, including the purchase of a portable sawmill and the establishment of a medium-scale honey enterprise.

In Niger, the participants of the first MTG course went on organise and deliver a second course without the direct involvement of any Australians.

In Indonesia, a year after being involved in delivering a MTG course, I (the author) met a number of participants who had begun pruning their timber trees and I heard that they were actively involved in training other farmers within their community to do the same. A similar impact was identified by reviewers of the Australian MTG courses (Bauer and Gordon 2003).

Formal evaluation of the long-term impacts of the MTG course is now required to determine the degree to which the MTG courses have changed farmers' behaviour and, if so, whether these changes are likely to deliver long-term economic, social or environmental benefits to the landholders and their communities.

In Timor-Leste, the MTG courses have directly supported the existing WithOneSeed program.

Supporting and enhancing farmer-to-farmer extension

A fundamental tenet of the MTG and PGM extension model is that communication between farmers, both passive (observation) and active (conversation), plays a critical role in the adoption of agroforestry.

> My field trip highlight was Joseph's farm. It blew my mind away. I have never seen anything like that. The diversity of tree species in his house setting was incredible. I aspire to be like that one day. I am very grateful to Master TreeGrowers.
>
> — MTG participant Ntungamo, Uganda

Encouraging farmer-to-farmer communication by supporting farmer information networks and peer mentoring has the potential to drive agroforestry development. As part of the Indonesian MTG program, a group of leading farmers from 3 regions were selected to trial farmer-to-farmer mentoring. Following a 2-day training course, the farmers were resourced and encouraged to visit farms in their own communities.

For his review of the Indonesian MTG courses, Dr Muktasam travelled to each region to review the trial and found that only the team from Bulukumba had implemented the plan as proposed. In the other regions, he determined that the selection of participants was not appropriate, and those farmers who were keen to be mentored felt that they lacked support and guidance.

The experience highlighted that the PGM model is a difficult concept for many landholders and forestry professionals, particularly those living in communities where there has been a strong history of top-down forestry extension with forest officers giving 'expert' advice to landholders. The trial in the Bulukumba region had support from the leadership of the local forestry department, who clearly understood both their role and that of the mentors. The Bulukumba team implemented the work plan, supported their mentors, and were able to clearly identify how the mentoring led to improved tree management practices on farms.

These mixed results in the mentoring trial in Indonesia reflect our experience in Australia where the Otway Agroforestry Network has sought to guide landholder groups in other regions to develop and implement PGM programs. While, in each case, the participants were enthusiastic and their site visits were clearly valued by the recipient farmers, none of the programs have received ongoing funding or ongoing support from local agencies. In these regions, large publicly funded grant programs continue to provide farmers with 'expert' advice and direct funding to implement single-purpose revegetation programs.

The MTG and PGM programs as an alternative extension model

The MTG approach is clearly very different to that adopted by many of the existing agroforestry extension programs in Africa, Southeast Asia and the Pacific region in that it does not advocate any particular agroforestry systems or species. The MTG program simply aims to facilitate and support farmers' decisions by giving them fundamental knowledge (for example, plant science, tree measurement, silviculture), sharing market information (for example, specifications, prices) and encouraging group discussion and evaluation. Rather than using direct incentives (for example, free trees, grants) or regulations to entice farmers to establish or manage trees that the authorities or industry want, the MTG approach encourages farmers to design and implement tree-planting projects that reflect their interests.

In Australia, the MTG program has been running for more than 25 years and remains the only national agroforestry or farm forestry extension program. The Australian Agroforestry Foundation is strongly focused on supporting farmer decision-making and has no agenda for the type of trees planted or the way they are managed. With philanthropic and government support, the foundation, or its partners, have been able to deliver the international MTG courses in a similar manner.

In both Indonesia and Vanuatu, the aim of the Australian Government program was to introduce the MTG model and explore whether it could be adapted for delivery by the relevant government department. While government agencies and their staff are important partners in the delivery of MTG courses, there are risks involved in having the government agencies delivering these programs. In Vanuatu, for example, past forestry extension programs have largely involved the distribution of free trees or the establishment of demonstration sites by the Department of Forestry. The same may be true of some NGOs or industry groups that promote particular tree species, product options or environmental and social objectives. It is important that the MTG program not be seen as promoting any particular interest other than those of the participants.

Among the Indonesian research team there was a strong view that the MTG program took a very different approach to that generally adopted by forestry extension agents in that country (Muktasam et al. 2021). They saw as novel, within their national context, the early focus on market specifications and prices, and the sharing of measurement techniques, which had largely been the preserve of the forestry profession.

Table 13-2 provides a comparison of the Australian and international programs, highlighting differences and similarities. Although there are clearly significant cultural, political, social and economic differences between farmers in Australia and farmers in developing countries, the evaluation of the various international courses suggests that the underlying extension and education philosophy of the MTG and PGM programs is transferable. Where landholders are largely free to make land-use decisions, particularly about managing trees, crops and livestock, and believe that they have a degree of secure land and tree tenure, participants in all the countries, irrespective of their relative wealth or education status, seemed to have a strong affinity with the philosophy of the MTG program. As in Australia, farmers in many countries lack access to local market information, an understanding of tree growth and production, and the basic tree establishment and management skills required to be able to design and manage personally appropriate agroforestry systems.

Although more detailed research is required, the experience to date suggests that, irrespective of country, location, farming system or culture, the MTG approach may have value wherever the following fundamentals apply (Reid 2017):

- Farmers' decisions about land management have a direct impact on the economic, social and environmental values of their own farm and the wider rural landscape.
- Farmers, and those who work with them, seek information from a wide range of sources and tend to validate and evaluate knowledge against their own experience and that of their trusted peers.
- Irrespective of their level of formal education, most landholders do not have a good understanding of tree growth, measurement and management, but are keen to apply some of the basic concepts and practical implications of tree physiology, wood formation, diameter assessment, branch pruning and thinning on their own properties.
- There are professionals, researchers and development workers who seek to encourage tree growing on farms, but lack the confidence, techniques and the tools required to effectively convey the principles of agroforestry design and management.

The key to success lies in ensuring that the key presenters and community leaders involved in delivering and supporting the courses understand the MTG approach and the focus it places on landholders making their own management decisions. To ensure this is the case, it is important that prospective coordinators are engaged and trained and receive ongoing mentoring in the delivery of courses (as was trialled in Indonesia).

Table 13-2: Qualitative comparison of Australian and international MTG programs

<table>
<tr><th>Criteria/Issues</th><th>Australian MTG programs</th><th>International MTG programs</th></tr>
<tr><td>Program philosophy</td><td colspan="2">The participatory model applies wherever landholders are the principal decision-makers on the adoption of agroforestry practices.

The MTG program philosophy is equally confronting (in Australia and internationally) to many locally influential professional extension agents and government or industry agencies who use a traditional top-down extension model.</td></tr>
<tr><td>Course framework</td><td colspan="2">The 5-part MTG framework (Table 13-1) has proved adaptable and suitable for both Australian and international MTG courses. The early focus on farmer aspirations and market specifications appears to represent a very different approach from past farmer educational programs.</td></tr>
<tr><td rowspan="2">Course design and delivery</td><td>8-day program delivered over 6–8 weeks</td><td>4- or 5-day program delivered over consecutive days</td></tr>
<tr><td colspan="2">Noted advantages of the longer course structure in Australia suggest there is a need for follow-up activities (particularly farm walks) in the period after the international courses to allow landholders time to appreciate the importance of appropriate design, consider the information being provided and review their management plans.</td></tr>
<tr><td rowspan="2">Participant characteristics</td><td colspan="2">Mostly family farmers who believe they have legal or customary rights to make land-management decisions about a parcel of land, and believe they have long-term tenure of the land and any trees or tree products they grow.</td></tr>
<tr><td>Mostly commercial farmers, many of whom have off-farm income. Most can contribute to the costs of the course, although some find it difficult to attend all sessions due to work commitments.</td><td>Mostly subsistence farmers, who must first provide for the household needs. Few can contribute to the costs of the course and those travelling long distances may require accommodation and travel support.</td></tr>
<tr><td>Partner characteristics</td><td>Commonly local landholder groups and/or government agencies providing local conservation and land management extension programs.</td><td>Various partners including internationally supported NGOs, research and development organisations and government agencies. Less leadership by local extension agencies or landowner groups.</td></tr>
<tr><td>Financial considerations for project delivery</td><td>Local extension agencies, sponsors and participants are generally able to share the costs.</td><td>Higher travel costs for international presenters. Greater need for the program to support local participants and presenters.</td></tr>
<tr><td>Provision of ongoing support</td><td>Opportunities for landholders to maintain links with the program through regional landholder groups, national organisations, or direct contact.</td><td>The difficulty for individual participants to access ongoing support highlights the critical role for local agroforestry networks (Kabale, Uganda) or locally staffed NGOs (Timor-Leste).</td></tr>
<tr><td>Potential for Peer Group Mentoring programs</td><td colspan="2">Provision of a PGM program, including the training of landholders and the provision of peer support, relies on the presence of a well-led and locally resourced landholder organisation or supporting NGO.</td></tr>
<tr><td>Challenges</td><td colspan="2">Both within Australia and internationally, the development of a successful participatory agroforestry education and extension program may be undermined by programs run by governments or NGOs that advocate and promote agroforestry practices without regard for individual landholder needs, resources and aspirations.</td></tr>
</table>

Conclusions

While the MTG course and the PGM program cannot directly address legal, political, security or resource issues that may be limiting agroforestry development in particular locations, the application of the Australian model in several developing country communities has demonstrated that effective extension and education can have a significant impact on farmers' understanding, confidence and enthusiasm for growing trees. It is also clear that the MTG and the PGM approach is very different to that generally adopted by agroforestry development projects in many countries.

As the Australian Agroforestry Foundation continues to work with partner organisations to deliver MTG courses around the world, ongoing monitoring and evaluation will be required to determine the degree to which the MTG course and any follow-up support provided to the participants results in the type of on-ground outcomes that Bauer and Gordon (2003) noted in Australia – that is, greater adoption of purposeful tree planting on farms by both participants and their neighbours.

References

Bauer M and Gordon J (2003) *Evaluation of the agroforestry and farm forestry program: an overview of all projects - Stage 1*, Rural Industries Research and Development Corporation, Canberra, Australia.

Beyond Subsistence (2014) 'The Ntungamo, Uganda, Africa, Master TreeGrower Course' [Appendix report for The Crawford Fund], Beyond Subsistence, Yarram, Australia, not published.

Curry D and Reid R (2009) 'Peer group mentors contribute to diversified, sustainable and innovative farming communities', paper presented at the *Australasia-Pacific Extension Network 5th International Conference: shaping change in communities - dimensions of excellence*, Abbey Beach Resort, Busselton, Western Australia, 9–12 November 2009.

Muktasam A, Reid R, Race D, Wakka AK, Oktalina SN, Agusman, Herawati T and Bisjoe ARH (2019) 'Enhancing the knowledge and skills of smallholders to adopt market-oriented tree management practices: lessons from Master TreeGrower training courses in Indonesia', *Australian Forestry*, 82:4–13.

O'Meara T and Wright J (1999) *Evaluation of the Australian Master TreeGrower Program*, Rural Industries Research and Development Corporation, Australian Government, Canberra, not published, accessed 1 August 2022.

Reid R (2008) *Tree change: the Australian Master TreeGrower phenomenon*, RIRDC Publication No. 08/129, Project No. UM-63A, Rural Industries Research and Development Corporation (RIRDC), Canberra, Australia.

——(2017) 'Developing farmer and community capacity in agroforestry: is the Australian Master TreeGrower program transferable to other countries?', *Agroforestry Systems*, 91(5):847–865.

Reid R and Deans W (2009) *The Australian Master TreeGrower Program: providing a sound foundation for Australian agroforestry*, RIRDC Publication No. 09/157, Project No. 000613, Rural Industries Research and Development Corporation, Canberra, Australia.

Reid R, Syafii S, Oktalina SN, Manalu P, Rohadi D, Herawati T, Rizal A, Nurhaedah, Sumirat, Hayati KN, Irawanti S, Julmansyah and Setiawan A (2014) *Research task 4: design, delivery and evaluation of an alternative farmer learning approach to enhancing the capacity of farmers to participate in community based commercial forestry in Indonesia*, [report for ACIAR project FST/2015/040, 'Enhancing community-based commercial forestry in Indonesia'], Australian Centre for International Agricultural Research, Canberra, not published, accessed 1 August 2022.

Chapter 14

Using extension based on action research in developing tree-based programs for smallholders in Papua New Guinea

Robert Fisher, Micah Scudder,
Grahame Applegate and Nathan Wampe

Abstract

Many development programs and projects that are aimed at improving livelihoods through small-scale forestry or agroforestry do so with plans to provide specific packages and models, which they intend to promote and support. It is often assumed that once the models are 'right' they will be widely adopted. This is contradicted by the common experience that these packages are often rejected or adapted by farmers. Experience also shows that not all farmers want the same package, nor are there packages that are universally suited to the diverse circumstances of all farmers, even in the same socio-ecological context.

In this chapter, we look at the underlying models of small-scale forestry and agroforestry research and extension that inform the traditional approach. We argue that the approach is based on an outdated and inadequate theory of extension, which is reinforced by the requirement of development programs to achieve standardised and easily quantifiable targets. We recommend an alternative participatory model based on action learning and action research. The alternative model has been well tested, but remains dominated by the traditional approach, probably because the latter fits the requirements of the foreign aid paradigm.

Our research in Papua New Guinea (PNG) found that for smallholder tree-based interventions with a livelihoods or commercial focus, several aspects need to be considered, particularly farmers' capacities, farmers' appetite for risk, the availability of markets, and the labour and capital requirements of the proposed interventions. We also discuss risk as a factor that affects decision-making whereby farmers balance the value of increased yield against labour and capital inputs.

Acknowledgements

We wish to acknowledge the communities with whom we worked in the Ramu–Markham Valley and the industry members from Morobe Province who generously provided their time and ideas during our work on the project. At various stages, several Ramu Agri-Industries Ltd staff members were attached to or active in the project. We wish to thank Melinda Thom, Clifford Single, Zephaniah Waviki and Regina Kagl for their enthusiastic and important contributions. Kanchana Wiset and Jack Baynes were important members of the project team. Jack was a team member during the 2 phases of the ACIAR project before his retirement. In particular, he pointed out the limitations of the plan to carry out 'species preference studies' and helped switch the focus to understanding what services people wanted from trees rather than which species they preferred. This was an excellent example of adapting planned activities in the spirit of action research.

Introduction

Contemporary forestry programs frequently aim to contribute to both sustainable forestry (including forest restoration) and improved livelihoods for rural people living in and around forests. Project interventions often promote sustainable practices through what can broadly be defined as forestry extension.

The problem is that internationally funded projects continue to set targets based on uptake of technical packages of crops or forestry practices. While these packages are often designed and tested in collaboration with farmers, the testing process is often unrealistically rapid and there is often an assumption that a single package or a small number of packages will be attractive to a wide variety of farmers. This approach fails to consider participatory and learning approaches to agricultural extension, to which forestry extension methods are closely related. The persistence of target setting in extension can probably be best explained by the fact that donors prefer to use logframes with set targets because they are relatively easy to measure. The focus on testing single packages is harder to explain, except for an apparent failure to recognise that farming communities are not homogeneous and the contexts within which individual farmers make decisions are highly variable.

We explore experiences in forestry research and extension in PNG to demonstrate the need for a more patient approach that adapts solutions to local context and the needs of farmers. Experiences from 2 components of an applied research project are discussed.[19] The first activity discusses a forest restoration project in the Ramu–Markham Valley (RMV) in northern PNG where small-scale farming was mixed with tree growing. The second activity examines research on the current efficacy of small-scale timber production and marketing in Morobe Province.

Early and common practices in agricultural extension were associated with land-grant universities in the United States, generally following linear linkages between research and extension. In such linear processes, researchers developed new agricultural technologies and extension officers provided education to farmers on these practices in what is often referred to as the transfer-of-technology approach. Under this approach, scientists develop the technological packages, then extensionists educate (or convince) farmers to adopt these innovations. The World Bank applied the transfer-of-technology approach to its training-and-visit approach.

A major strand in thinking about agricultural extension is associated with the work of Everett Rogers, a rural sociologist from Ohio State University, on the 'diffusion of innovations', first published in 1962 (Rogers 2003, 5th edition). Rogers was interested in the adoption of innovations in a wide variety of contexts, but his work was particularly influential in agricultural extension. An important aspect of his work was his typology of innovation adopters.
He proposed that adopters of innovations could be classified into 5 categories:

- innovators (the quickest to adopt innovations)
- early adopters
- early majority
- late majority
- laggards.

19 The project 'Enabling community forestry in Papua New Guinea' (2017–2022) (FST/2016/153) was funded by ACIAR and implemented by the University of the Sunshine Coast. Research in the RMV was done in collaboration with Ramu Agri-Industries Ltd, and in Eastern Morobe Province with the Timber and Forestry Training College at UNITECH, Lae.

Those in the latter 2 categories were seen as being typically tradition-focused, having low social status and being relatively poor. These perceptions, and similar assumptions about the process of adoption of agricultural innovations and the characteristics of the adopters, are still fairly widely accepted.

Problematically, Rogers' model of change treats adoption as being related to the characteristics of individual recipients and understates the content of the message and its relevance to them. Beyond broad characteristics, it does not explain why people tend to be 'early adopters' or 'laggards'. A more nuanced approach to understanding adoption seeks to understand why people would choose to adopt or not adopt particular innovations.

Many of the causes of ineffective extension have been identified by Vanclay (2004) who argued that understanding social issues and the social nature of adoption is essential to effective agriculture extension. He identifies 27 principles underlying his recommended approach.[20]

Here are some of the most important:

- Farmers are not all the same.
- Adoption is a socio-cultural process. In other words, it is not just a process of one-way communication between scientists and farmers. Adoption results from 'a deliberate decision by an individual farmer in response to a consideration of a wide range of issues'.
- Women are an integral part of the farm.
- Farmers construct their own knowledge.
- Effective extension requires more than the transfer of technology; it requires an understanding of the world views of farmers.
- Farmers have legitimate reasons for non-adoption.
- Group extension is not a panacea.

Among factors contributing to why people might not adopt a particular innovation are the lack of available labour and the cost of labour. Sometimes the lack of available labour can result from complex social factors. For example, Mak (1997) explored reasons for the reluctance of farmers in Cambodia to adopt green manuring to improve rain-fed lowland rice production. Although research had demonstrated the benefits, the labour was not available to protect the leguminous plants from wandering cattle. The production of palm sugar, virtually the only source of cash income available in the villages studied, took precedence. During the season when the legumes were growing in paddies, men were busy collecting sap from sugar palm and women were busy boiling the sap to reduce it to palm sugar. The labour shortage was compounded by the age structure of communities, which, due to the genocide of the Pol Pot era (1975–1979), had very few older people to look after children and other domestic chores.

Another important factor behind reluctance to adopt new technologies is risk, including a specific type of risk described as 'subsistence risk' (Scott 1976). Referring to Southeast Asia, Scott argued that in good years poor farmers might benefit from adopting new agricultural technologies, such as high yield varieties; however, in bad years those who lived close to the margin required for survival would face disaster if crops failed.[21] Another factor associated with non-adoption relates to technological packages, which do not fit the individual needs of farmers or the social context. As we argue below, the social context is crucial in the case of the RMV.

20 While Vanclay's conclusions are largely based on research with farmers in Australia, the principles have much wider application.

21 Rogers does note the importance of wealth but does not look at the heightened vulnerability to risks associated with poverty.

While early approaches to extension were clearly top down and expert-based, more participatory and learning-based approaches to extension emerged in the 1980s. This shift to more participatory and adaptive extension followed earlier transformations of thinking about rural development which advocated putting people at the centre of rural development. This is exemplified in the work of Chambers (1983) on rural development generally and Westoby (1975) specifically on forestry. The emphasis was on focusing on what poor rural people need rather than on national priorities.

The shift towards participatory approaches in sustainable agriculture and towards the role of extension agents as facilitators is exemplified in the edited volume by Roling and Wagemakers (1998). One example of participatory extension was the farmer field school approach introduced by the FAO in 1989 in Indonesia (FAO 2015). Farmer field schools were first used to introduce integrated pest management when researchers became concerned that overuse of pesticides was causing serious problems. Since that time, they have been applied to a variety of agricultural issues and have also been adopted in forestry extension.[22]

Farmer field schools involve facilitated learning-based field programs with groups of farmers (Box 14-1).

Box 14-1: Farmer field schools

The FFS [farmer field schools] approach, developed by FAO and partners nearly 25 years ago in Southeast Asia, promotes farm-based experimentation, group organisation and decision-making.

This learning-by-doing approach, adopted by the IPPM [Integrated Production and Pest Management] program, provides a risk-free setting in which to discuss, dissect, modify and experiment with new agricultural management ideas.

In a typical FFS, 20-25 farmers meet once a week in a local field setting, under the guidance of a trained facilitator. They observe and compare two plots, one following local conventional methods, the other experimenting with 'best practices', and conduct experiments to solve technical problems. This allows the farmers to investigate a wide range of topics, such as:

- management of soil fertility and water resources;
- methods of local varietal selection and issues of seed quality;
- risks associated with toxic pesticides and implementation of low toxicity alternatives and integrated pest management;
- farm management and marketing skills; and
- diversification of farming systems.

At the end of the season, the FFS group holds a field day to show local politicians, government agriculture workers and other farmers what they are doing. Exchange visits with other FFS are also encouraged.

Source: FAO 2015

22 See: www.fao.org/farmer-field-schools/ffs-overview/forestry/en/ (accessed 4 October 2023)

The Master TreeGrower (MTG) training courses for farmers in Indonesia followed the farmer field school model and aimed to assist smallholders develop skills to implement 'market-oriented tree management practices'. The training took participants to market hubs to observe relevant practices. Muktasam et al. (2019:4) described experiences with the MTG program and reported on an evaluation, which 'revealed that the courses were effective in increasing smallholders' knowledge of commercial forestry and their silvicultural skills' (see **chapter 13** for details).

Another example of a participatory learning-based approach to extension is the farmer-back-to-farmer model developed at the International Potato Center in Peru (Rhoades 1984). In this approach, farmers first identified technical problems related to potato production and storage, then scientists developed technology, with farmers completing the cycle by assessing and modifying the technology. This process reverses the normal linear pattern of extension (scientist–extensionist–farmer).

These alternative approaches to agricultural extension are also evident in forestry extension, which exhibits many of the features of the various approaches to agricultural extension. In an overall review of forestry extension, a clear distinction emerges between the transfer-of-technology approach and an alternative approach in which 'extension should view people as partners' (Anderson and Farrington 1996). These authors see forestry extension methods as 'evolving away from the traditional, top-down approach.' They add that this view of extension 'has a strong recent history in forestry – especially within community or social forestry'. A recent example is described in Muktasam et al. (2019).

Kaudia and Omoro (2001:1) reviewed experiences of farm forestry extension in Africa in the very early 2000s, focusing on the future role of technical extension agents. They found that participatory extension was becoming more common, but note that:

> Lack of clear methods for practical application of concepts like participation, empowerment and facilitation is hindering progress. But where these concepts have been applied practically, communities have demonstrated a capacity to be responsible for extension service delivery.

While these observations date back 2 decades, they resonate with contemporary experience.

Action research is a methodology closely related to participatory and learning-based extension. It has been widely discussed and applied in natural resource management and forest management for several decades, where it combines action in conservation and resource management with research and learning. Action research is based on the idea that learning and research contribute to better action and that learning occurs as a result of observing the outcomes of action. It involves continued cycles of action, observation and modified action. Importantly, in the context of forestry, farm forestry and similar activities, action research provides an opportunity to start where there is uncertainty about context and then to modify what is done.[23] Box 14-2 describes some of the features of action research and action learning.

23 For a broad review of action research and participatory action research, especially in relation to forestry, see Fisher and Jackson (2022).

Box 14-2: Action research and action learning

'Action research differs from the more common linear approach to applied research in that it combines action and research and involves a group of people around an issue or concern. It involves consciously and systematically, moving through a series of repeated cycles of action, observation, reflection and planning. While more conventional applied research often involves the scientists going away to solve a research problem on behalf of a client, action research involves investigating issues at the same time as attempting to address them – learning by doing and learning from doing. The solutions are tested and modified as the research proceeds.

[...] Action research is a process of learning in order to act more effectively in a particular situation.

[...] Both action learning and action research are useful when:

- A situation or issue is complex with many unknowns (and therefore not suitable to a reductionist approach
- A situation is changing
- The starting point is not clear
- There are multiple stakeholders involved.

These situations commonly apply in cases involving the management of environmental and natural resources by humans.'

Source: Fisher and Jackson (2022:222–223)

Research locations and process

In this chapter we discuss 2 separate activities carried out in northern Papua New Guinea. The first of these activities involved forest landscape restoration through farm-based forestry and agroforestry in the RMV. The second involved exploring the factors affecting the success of small timber operations in Morobe Province.

Forestry extension in the Ramu–Markham Valley

The Ramu–Markham Valley (RMV) actually comprises 2 valleys running between the mountain ranges along the north coast of PNG and the main highland ranges, which separate northern and southern PNG. The rivers that run through each valley are the Ramu and the Markham, which flow to the west and east respectively. The catchment boundaries of the 2 rivers are not easily recognisable and it is convenient and common to refer to the RMV as a single valley. The forest restoration component of our project occurred in the central part of the RMV, where 2 provinces meet. The lowland portion of this part of the valley is dominated by anthropogenic grasslands, with more extensive forests on mountain slopes.

The local people are mostly engaged in small-scale agriculture or home gardening. Crops are produced primarily for home consumption, with any surplus being for sale in local markets.

Several commercial agricultural companies are operating in the valley. Of these, Ramu Agri-Industries Ltd (RAIL) produces sugar, oil palm and beef. The company strongly emphasises social responsibility and environmental sustainability, which it links with the company's legal obligations to restore or maintain tree cover in designated areas. Other social and environmental sustainability obligations arise from RAIL's need for certification under the Roundtable on Sustainable Palm Oil. Because of its responsibilities for and commitment to environmental restoration and community relations, RAIL was a natural commercial partner for research about reforestation and community forestry. It had previously been a partner in ACIAR forestry projects, including an earlier phase of our project.

The evolution of project interventions in the RMV

Understanding the evolution of interventions during the history of 3 separate ACIAR-funded projects in the RMV spanning the period from 2007 to 2022 shows how much the knowledge gained from these projects led to subsequent project activities being modified:

- The first project that operated in the RMV, in cooperation with RAIL, was implemented by the Australian National University (ANU). Titled 'Value-adding to PNG agroforestry systems' (FST/2004/050), the project ran from 2007 to 2014, and we refer to it here as the ANU project.
- The second project, implemented by the University of the Sunshine Coast (UniSC), with RAIL as an implementing partner, was titled 'Enhancing the implementation of community forestry approaches in Papua New Guinea' (FST/2001/057). It ran from 2013 to 2017. For clarity, we refer to this as the first UniSC project.
- The third project, essentially a second phase of the previous project, was titled 'Enabling community forestry in Papua New Guinea' (FST/2016/153) and ran from 2017 to 2022. We refer to this as the second UniSC project.

While the focus of activities was different in the 2 UniSC projects, both aimed to enhance community forestry.

The role of clans in enhancing community forestry

The aim of the ANU project to add value to PNG agroforestry systems was 'to further the adoption of commercial-scale high-value tree growing by landowners of PNG' (ACIAR 2014). Though its concerns were distinctly different from those of the 2 subsequent UniSC projects, one activity – the development of nurseries to produce seedlings for planting by farmers in the RMV – had a flow-on effect on these projects. A nursery was established at the project level, serving multiple villages and multiple clans; however, it was under-used. Anthropologist Hartmut Holzknecht (2014 and several personal communications), who was an adviser to the ANU project and to the first UniSC project, reported that the nursery was ultimately unsuccessful because not all clans were represented in the management structure. The nursery was subsequently managed by a single paid employee. While the nursery continued to operate during the ANU project, it was found that people from outside the village where it was located rarely took seedlings from the nursery, assuming it was 'not for them'. This led to a major shift in approach in the first UniSC project, to working with individual clans rather than with multiple clans and communities.

The nature of land ownership and its relationship to social structure in PNG is important and is discussed in Box 14-3.

Box 14-3: Customary land ownership and social structure in PNG

In PNG almost all land (normally recognised as being about 97% of land) is held under customary tenure. This is recognised under the PNG Constitution. Under customary ownership, land is owned by clans with hereditary membership. In different parts of PNG, clan membership is inherited according to different customs. In most parts of the country, including the RMV, clan membership is inherited through a patrilineal system (that is, through the male line), with all male descendants of a clan member becoming clan members. In some parts of PNG, clan membership and associated land ownership is inherited matrilineally (that is, through the female line).

In the RMV, clan leadership is not inherited and leaders are not formally elected or appointed by the government. Rather, leadership is achieved by an individual's prestige, which could be a result of leadership skills, wealth or other factors. Clans often recognise several leaders. Sometimes these leaders are in conflict with each other, and they are often members of different factions. Decision-making is not carried out by leaders acting as a formal committee, but rather by informal interactions and negotiations. A consequence of this is that decisions about changes to land use are not simple, and outsiders advocating change usually need to make repeated visits, have repeated discussions and work with multiple stakeholders.

The first UniSC project to enhance community forestry (2013–2017) was focused on community forestry rather than growing high-value trees, and the emphasis was on working with clans or subclans to reforest land for a combination of conservation and livelihood benefits. Efforts were also made to support collaboration between clans, although it was recognised that this was not easy. Small nurseries were developed with clan or subclan members to provide seedlings to plant areas of land not allocated to households for gardens. Initially, some efforts were successful, mainly at the level of subclans, but subsequently disputes developed with other clan members. This led to the recognition that reforestation of clan-owned land not used for gardens was in conflict with customary tenure and land-use decision-making.

A project report on the social dynamics of decision-making for community forestry (Fisher 2017) examined decision-making in the context of project experiences and concluded that clans are not normally involved collectively in economic activity. Economic activity, principally gardening, tends to occur at a family or household level. Clans make decisions about how land can be used and by whom it can be used. These findings were consistent with much of the anthropological literature on PNG generally, and certainly fitted what was known about the RMV. While there was nothing especially new about these findings, a nuanced understanding of the role of clans in decision-making had not been applied to forestry.

Importantly, these insights into decision-making about forest use were gained from observing what local people were doing and recognising that assumptions about ways to implement forest activities were leading to lack of interest. Frequently, some people expressed and showed interest and enthusiasm for activities, but others, including family members, showed no active interest. Continued interaction and dialogue with local people were essential to understand what they wanted to do and what they did not want to do.

Towards the end of the first UniSC project to enhance community forestry in the RMV, emphasis began to shift towards family-based agroforestry as a way of increasing the number of trees in the landscape, while recognising the need to work with clans about the overall direction of activities.

This story is about evolution from an area-based notion of community forestry to a clan-based model, and then towards an approach that recognised the role of clans in what can be thought of as land-use policy combined with the economic activities of individuals and families, with gardening being the central economic activity. In this context, we use the word 'economic' to refer to productive activity, including livelihood activities.

Focusing on family-based forestry did not imply a shift away from clans. In fact, as described in Box 14-3, decision-making about land use operates at two levels, with clans making broad decisions and individual farmers making decisions about use of their family plots.

The shift to family-focused forestry

The aim of the second UniSC project, 'Enabling community forestry in Papua New Guinea' (2017–2022), was 'to improve rural livelihoods through family-focused community reforestation and small-scale harvesting and processing in PNG' (ACIAR 2022), specifically in the RMV and the Eastern Highlands of PNG. This chapter deals only with activities in the RMV.

The project was designed based on a logical framework (logframe), complete with objectives, activities for each objective and outputs. An important theme in this chapter is that this type of design was too prescriptive from the start and did not fit the necessary need for adaptation based on experience and learning as the project was implemented.

The 2 objectives relevant to the community forestry component in the RMV were to:

- design and test novel tree-based livelihood systems for family-focused, community-based reforestation
- identify the methods by which family-focused, community-based reforestation could be scaled out to a landscape scale.

In other words, the plan was to separate activities into 2 steps: designing and testing systems, and upscaling activities to a wider scale. A problem with this 2-step process is that it ignored the need for time to test the biophysical activities (nurseries, identifying appropriate species, pilot planting) and the social processes involved in local people learning techniques, deciding what they required, and making clan-level and individual decisions about what to plant and where to plant it. Just as trees need time to grow, social processes such as decision-making take time. Squeezing these processes into a 5-year time frame (as originally intended), along with a scaling-out phase involving wider adoption, proved to be a design flaw. Delays in planting trials due to drought, and loss of over 2 years for most project activities due to the COVID-19 pandemic, made achieving the objectives even more difficult.

Engaging with pilot communities

The initial plan for implementing field activities was to select 2 pilot communities, focusing on specific clans, and to work with those clans to decide what, where and with whom to carry out initial planting pilots. After reviewing options, 2 communities were selected and extensive negotiations began. The initial steps included selecting somebody from within each clan to manage the local nurseries that would provide seedlings for out-planting, and training selected volunteers to manage seedlings before planting them in their own fields.

In both communities, clan leaders and members agreed to the plans, but conflict between 2 people about responsibility for nursery management delayed progress in one community. This ultimately led to the suspension of project activities in that pilot community and another pilot community was selected. The new community was well known to RAIL staff and the people were actively interested in tree planting, largely due to an enthusiastic local farmer. Negotiations were relatively straightforward and progress was relatively quick.

In undertaking negotiations and sharing information, the process involved frequent project staff visits, community meetings and discussions with individual clan members. No project activities were implemented without community members being able to understand suggestions, assess them and voluntarily agree. In any case, if people did not want to take on a suggested activity, they could simply 'vote with their feet' and ignore it. Thom et al. (2019) reported an example of women (in Phase 1) 'voting with their feet' when a male landholder agreed with the project to establish an agroforestry plot of one hectare. The women, who would be doing the work, instead established a much smaller plot as they were not willing to do so much extra work. They 'exercised their power simply by deciding what work to do.'

As these 'community engagement' activities took place, the project team members were also exploring options for technical agroforestry systems to be subsequently tested by community members. They identified useful and locally available tree species for agroforestry systems, along with options for growing these species in plots with horticultural crops and other tree species for the purposes of nitrogen enrichment, shading and the production of mixed products for consumption and, if appropriate, for sale.

Identifying preferred services instead of preferred species

The project design included the identification of preferred species by communities. Project staff rejected the idea of the community members picking their preferred species because they felt that this could lead to people selecting species with which they had little or no experience, species that were not suited to local conditions, or species that were not easily available.

Instead of focusing on preferred species, Kagl et al. (2020) investigated what 'services' people wanted from trees, such as producing food for consumption, producing products for sale, or 'environmental' services such as shading crops. Some of the key findings and implications were particularly relevant as they affected the future implementation of the project, including the way technical packages and advice were developed:

- Interest in agroforestry was common among the people interviewed and there was considerable enthusiasm for establishing nurseries.
- 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.
- There was 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.
- Despite the researchers' intentions to avoid raising expectations (although this was seen as a forlorn hope), expectations were raised and these expectations would need to be carefully managed as more specific discussions with potential participants occurred. This was a particular risk as it was unlikely that trials would begin before the 2019 planting season and there was a long time for expectations to germinate and lead to disappointment.

- The purpose of this study was to obtain some indication of the range of services potential participants in the agroforestry trials may be interested in. This information would help the project forestry team to design agroforestry trials that were both viable and desired by participants. The question was raised as to 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 trial participants.

Source: Adapted from Kagl et al. (2020:7–8)

The most useful contribution of this study of people's preferences was that it reinforced the importance of identifying the preferences of individuals as well as those of stakeholder groups. It also identified reasons why people might reject technology, such as the labour implications.

Listening to women in a male-dominated society

A second study implemented by the project explored the preferences of communities within the project area for tree and crop mixtures in gardens, preferred products from agroforestry, and differences between the preferences of men and women. This study was led by then PhD researcher Kanchana Wiset (see **chapter 3** by Wiset et al. for an account of the methodology, with specific findings for the RMV). A key finding of her research relates to a major difference between the preferences of men and women. The focus of women's concerns lay with the gardens they managed for household consumption. Men showed more interest in commercial crops, including cocoa, for which shading by timber trees is an advantage. Timber was seen by women and men as important for house construction, whereas growing timber for sale was seen as of limited importance given their lack of easy access to markets at the time, though some men expressed an interest in doing so in the future.

While RMV society is certainly male-dominated and land rights are inherited by men, our studies clearly showed that women have a greater role in decision-making than is often assumed. This was noted in project reports by Thom et al. (2019) and by Wiset et al. (2022).

Figure 14-1: A villager from the RMV (centre) discusses planting plans with PhD scholar Kanchana Wiset (right).

Credit: Robert Fisher

Developing and testing technology 'packages'

An important aspect of the project was the development and testing of technology 'packages'. This activity led to some very interesting outcomes. A major if simple idea was to plant trees that provide shade for cocoa, an important commercial product grown on a small scale by increasing numbers of farmers. Suggestions about spacing and species to shade the cocoa trees until they matured enough to tolerate the light were incorporated into the package.

Not surprisingly, it quickly became evident that people understood the need for shade. They went on to apply the basic concept but modified the shading species and the spacing for multiple reasons. Use of banana plants for shading was one adaptation. They also modified spacing and, rather than planting plots of recommended size (as envisaged in the project logframe), they planted in smaller plots, often on the edge of existing gardens.

The reluctance of farmers to plant larger plots makes sense, as there were many unknowns. They showed great interest in trying potential new ways of generating income or improving their livelihoods, but they saw the plots as experiments. They were prepared to invest labour to see what worked, but they understandably did not want to invest significant amounts of labour in planting and managing large plots when there was a risk of failure. Thus, partial adoption can be explained by a combination of labour demand and risk.

All of this highlights the error in designing a project to move too quickly from developing and testing to upscaling.

Figure 14-2: Farmers in the RMV are experimenting with cocoa as a cash crop. The market is limited but growing.

Credit: Robert Fisher

Figure 14-3: **A farmer in the RMV discusses the use of banana plants as shade.**
Credit: Robert Fisher

A summary of the extension method applied in the RMV

The extension methodology we applied in the RMV combined action research with participatory extension. It involved frequent visits to communities, discussions with individual community members and groups, and participant observation during farming and social activities. The project team paid particular attention to people's preferences for forestry and agroforestry, and revised plans in response to what they learned. Discussions about activities were in the form of dialogue rather than formal surveys.

On occasions, we organised focused studies to examine specific issues. These include the preferences study (Kagl et al. 2020), Wiset's study (2022) which revealed a major difference between the preferences of men and women, and a study of people's motivations for lighting fires (Wampe et al. 2019).

Small-scale timber harvesting and processing in Morobe Province

In the second major activity of our research in PNG, we explored the success factors of small timber operations in Morobe Province. A portion of the RMV lies within the north-western part of Morobe. The provincial capital, Lae — the second largest city in PNG – is located on the delta of the Markham River. Most of the small-scale timber-harvesting activities operate within an informal market characterised by selective logging and portable sawmilling, which occur outside the regulations and purview of the PNG Forest Authority. Following methods outlined by Yin (2009), we developed a descriptive case study on the small-scale timber operators. Semi-structured interview discussions were held with numerous informal market stakeholders. Our research objectives were to identify:

- who the informal market participants are
- how the informal market functions
- what specific factors led to operational success.

Our methods are discussed in detail in Scudder et al. (2019a).

Our study revealed that small timber operators can typically be separated into 3 groups:

- forest-resource owners
- portable sawmillers that produce rough-sawn lumber
- small-scale manufacturing businesses.

Some of the forest-resource owners owned sawmills and harvested timber from their own lands, while others sold their timber to individuals or manufacturing businesses that owned their own portable sawmills. It was common for these harvest arrangements to be made among relatives who owned forest resources.

The sawmillers typically sold lumber they produced to manufacturers, who further processed the rough-sawn lumber.

All the manufacturing businesses purchased rough-sawn lumber from portable sawmill owners. Some had their own portable sawmills and also entered into harvest agreements with forest-resource owners. These manufacturing businesses operated in both the informal and formal markets in that they purchased raw materials from informal market operators, who may or may not have paid taxes.

We found that most of the timber value is being captured by the small-scale manufacturing businesses. While forest-resource owners typically received larger payments than they could get from timber royalties in the formal timber market (Scudder et al. 2019b), the payment difference was minimal. The portable sawmillers were generally barely breaking even and were only making a profit when they harvested the most valuable timber species. This has resulted in portable sawmill operators 'high grading' the forest (harvesting only the most valuable timber) and continually having to travel further from Lae to source timber. The small-scale manufacturing businesses typically added more value to the rough-sawn lumber using moulding machines. The prices they received for the value-added products were often 4 times the production costs. Commercial timber operations were more prevalent in the areas around Lae than in the RMV. This is most likely due to the greater supply of timber in the areas around Lae, and the existence of a market for rough-sawn lumber through the small-scale manufacturers.

Figure 14-4: A sawmiller in Morobe Province producing rough-sawn lumber with a chainsaw milling attachment

Credit: Haydrian Morte

Most of the forest-resource owners and portable sawmillers have received little to no forest extension training in terms of forest management planning, basic business principles and silvicultural practices. Forest-resource owners typically harvested their timber to meet immediate monetary needs, the common ones being school-related expenses for their children and store-bought goods that they could not produce themselves. The small-scale manufacturing businesses typically received knowledge and training from organisations like the Timber and Forestry Training College.

The college provided educational training in portable sawmill operations and pursued quasi-commercial activities where they milled and fabricated value-add wood products. One of the commercial services they offered was to conduct the value-add processing for those portable sawmillers who did not own value-adding equipment. Value-add processing typically used moulding machines to create wood products such as planed structural timber, tongue-and-groove flooring, and weatherboard siding. Many of the small-scale businesses we spoke with used this service during the early years of their business.

Our interviews with the various stakeholders helped us understand how people chose to participate within the small-scale informal timber market and what their motivations were. This helped us develop several extension-focused policy options to help increase the financial returns to forest-resource owners and portable sawmillers, and to improve the sustainability of small-scale forest management (Scudder et al. 2021). A key component of these extension policy options was a recommendation to increase extension interactions with forest-resource owners to help them develop forest land management plans that address both their immediate and long-term interests or needs. We also recommended that more market-based knowledge and business training, such as basic accounting, be provided to forest-resource owners and portable sawmillers so that they would be better informed when making decisions about their forest-based activities.

Figure 14-5: Portable-sawmill training with a Lucas Mill

Credit: Michael Poesi

Conclusions

In this chapter we have argued that forestry extension needs to involve two-way communication about new technologies, rather than a linear flow of knowledge from scientists through extensionists to farmers. We have also argued that conventional project design, which sets out specific activities, outputs and targets, is not conducive to such an exploratory and participatory approach. This difficulty associated with conventional project design is often well understood by project implementors. It is not a new finding, yet, despite it being commonly recognised as an issue, the conventional approach continues. While advocates claim conventional project design can be flexible and open to variation, in practice it rarely works that way.

Action research takes more time than typical forestry extension, but this is a necessary investment. Action research allows technologies promoted by projects to be assessed by farmers, modified by projects and adapted by farmers. The more traditional approaches to extension often lead (perhaps, usually lead) to untested and inappropriate technologies being promoted and to these technologies not being adopted.

In the RMV work, the essential lesson was that people were enthusiastic about innovations that they thought would benefit their livelihoods. However, they were cautious about risks and individuals often looked for different outcomes. Extension that incorporated flexibility and continued communication was essential.

Finally, it is worth noting that the research described in this chapter had research outputs in the form of publications (Scudder et al. 2019a and 2019b; Wiset et al. 2022). It was about generating research, defined as public knowledge. But, most importantly, the action research provided a basis for improved interventions that addressed what local people wanted.

Insights

- Adoption is not just about what people want, but why they may be wary or cautious about technologies. Understanding why people accept or reject technologies is more useful than looking for 'adopter categories'.
- Not everyone wants the same technology or package. Extensionists need to understand why individual farmers (female and male) as well as different stakeholder groups accept or reject technologies.
- This understanding can best be obtained through dialogue, often while observing activities in the field.
- Providing 'technical' extension packages to farmers works best if these packages can be assessed and modified by individual farmers to meet their individual needs and preferences.
- People may appear to accept extension suggestions, often out of politeness, but may then 'vote with their feet' and simply not participate in activities or accept suggestions.

References

Anderson J and Farrington J (1996) 'Forestry extension: facing the challenges of today and tomorrow', *Unasylva*, 47(184).

ACIAR (2014) *Value-adding to Papua New Guinea agroforestry systems*, final report for project FST/2004/050, Australian Centre for International Agricultural Research, Canberra.

——(2022) *Enabling community forestry in Papua New Guinea*, final report for project FST/2016/153, Australian Centre for International Agricultural Research, Canberra.

Chambers R (1983) *Rural development: putting the last first*, Longman, London, ISBN 0-582-64443-7.

FAO (2015) *Building resilient agricultural systems through farmer field schools*, Integrated Production and Pest Management Programme, Food and Agriculture Organization of the United Nations, Rome, accessed 13 October 2023. https://www.fao.org/3/i4411e/i4411e.pdf.

Fisher RJ (2013) 'Learning through action: reflections on action research in natural resource management', in Ojha HR, Hall A and Sulaiman V R (eds) *Adaptive collaborative approaches in natural resource governance,* Earthscan Studies in Natural Resource Management series, Routledge, London and New York.

Fisher R (2017) 'Social dynamics of decision-making and collective action in community forestry in PNG' [appendix to final project report for ACIAR project FST/2011/057, 'Enhancing the implementation of community forestry approaches in Papua New Guinea'], Australian Centre for International Agricultural Research, Canberra, not published.

Fisher R and Jackson W (2022) 'Can activist engagements have research outcomes? the case of ACM and participatory action research', in Colfer CJP, Prabhu R and Larson AM (eds) *Adaptive collaborative management in forest landscapes: villagers, bureaucrats and civil society*, The Earthscan Forest Library series, Routledge, Oxford and New York.

Holzknecht H (2014) *Background information dossier: Upper Markham and Upper Ramu valley communities in the contexts of ACIAR project FST/2011/057*, [project report], Australian Centre for International Agricultural Research, Canberra, not published.

Kagl R, Wampe N, Thom M and Fisher B (2020) 'Preferences for family-based agroforestry in the Ramu-Markham Valleys' [appendix no. 153 to unpublished final project report for ACIAR project FST/2016/153, 'Enabling community forestry in Papua New Guinea'], Australian Centre for International Agricultural Research, Canberra, not published.

Kaudia AA and Omoro LMA (2001) 'Is the "technical expert" role of farm forestry extension agents fading? Recent experiences from Africa and implications for future extension programs', *The Regional Institute Online Publishing*, https://fennerschool-associated.anu.edu.au/IUFROFE2001/paper6.pdf, accessed 22 June 2024.

Mak S (1997) 'Rainfed lowland rice farming in Cambodia; a study of agricultural change' [doctoral thesis], University of Western Sydney, Hawkesbury, Sydney.

Muktasam A, Reid R, Race D, Wakka AK, Oktalina SN, Agusman, Herawati T and Bisjoe ARH (2019) 'Enhancing the knowledge and skills of smallholders to adopt market-oriented tree management practices: lessons from Master TreeGrower training courses in Indonesia'. *Australian Forestry*, 82:Sup 1:4–13, doi:10.1080/00049158.2019.1605681.

Rhoades R (1984) *Breaking new ground: agricultural anthropology*, International Potato Center, Lima, Peru.

Rice RE (2017) 'Intermediality and the diffusion of innovations', *Human Communication Research,* 43:532–544, doi:10.1111/hcre.12119.

Rogers E (2003) *Diffusion of innovations*, 5th Edition, Free Press, New York, NY, ISBN 978-0-7432-5823-4.

Roling N and Wagemakers A (eds) (1998) *Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty*, Cambridge University Press, Cambridge, UK.

Scott JC (1976) *The moral economy of the peasant: rebellion and subsistence in Southeast Asia,* Princeton University Press, Princeton, NJ, ISBN 0-300-02190-9.

Scudder MG, Baynes J, Applegate G and Herbohn J (2019a) 'Addressing small-scale forestry informal markets through forest policy revision: a case study in Papua New Guinea', *Land Use Policy*, 88:104109.

Scudder MG, Baynes J and Herbohn J (2019b) 'Timber royalty reform to improve the livelihoods of forest resource owners in Papua New Guinea', *Forest Policy and Economics*, 100:113–119.

Scudder M, Saliau C, and Applegate G (2021) *New Guinea's small-scale timber market: creating an enabling regulatory framework and improving financial returns to forest resource owners*, policy brief for ACIAR project 'Enabling community forestry in Papua New Guinea' (FST/2016/153), Australian Centre for International Agricultural Research, Canberra.

Thom, M, Wiset K, Borthwick F and Fisher R (2019) 'Gender, agroforestry and forest landscape restoration in the Ramu-Markham Valley', [appendix to final project report for ACIAR project FST/2016/153, 'Enabling community forestry in Papua New Guinea'], Australian Centre for International Agricultural Research, Canberra, not published.

Vanclay F (2004) 'Social principles for agricultural extension to assist in the promotion of natural resource management', *Australian Journal of Experimental Agriculture*, 44:213–222.

Wampe N, Fisher R, Applegate G and Baynes J (2019) *Anthropogenic fires in the Ramu-Markham Valley: underlying causes and motivations*, [project report for ACIAR project FST/2016/153, *Enabling community forestry in Papua New Guinea*, Australian Centre for International Agricultural Research, Canberra, not published.

Westoby JC (1975) 'Making trees serve people', *The Commonwealth Forestry Review*, 54(3/4):206–215.

Wiset K, Fisher R, Baynes J, Wampe N, Thom M, Jackson W and Herbohn J (2022) 'What could forest landscape restoration look like in the Ramu-Markham Valley of Papua New Guinea?', *Land Use Policy,* 121 (2022):106322.

Yin R (2009) *Case study research: design and methods*, 4th edition, Sage Publications, Thousand Oaks, CA.

Chapter 15

Forming smallholder–industry partnerships to boost reforestation and wood supply

Rodney J Keenan

Abstract

Family-owned and community-owned forests are significant sources of commercial wood with potential to increase supply to meet the rising demand for wood locally and globally. As people move from rural areas to cities and use less fuelwood and more packaging, paper, furniture and sophisticated construction materials, demand for wood products is changing. For other agricultural commodities across Asia, such as tea, rubber, oil palm, sugar and cassava, smallholder producers have become the dominant producers, following initial production of these commodities during the colonial era as large plantation estates on land granted by the state to corporate producers (Byerlee 2014). Wood production is similar, but the capacity to expand these large-scale plantations is limited (Brand 2019). Historically, these plantations were established on cleared natural forests owned by the state and allocated to corporations, but this is increasingly unacceptable in most parts of the world.

While partnerships between the wood industry and rural landowners are less common than with other agricultural commodities, potential exists to increase investment in trees and wood supply and provide profits and broader livelihood benefits for both parties (Mayers and Vermeulen 2002). However, these benefits have often not been realised. Challenges to increasing wood supply from smallholder producers include the decreasing size of farms and understanding how to best integrate wood into rural livelihood strategies. On small farms, family members provide management and labour focused on producing food crops for home consumption or sale. They also often rely on off-farm income. Rural land in the developing world is often informally owned or controlled (Byerlee and Rueda 2015). Farmers may not have security of tenure over land or the trees, they may lack access to financial capital to invest in trees for wood production, or they may lack information on growing trees for different markets (Byron 2001).

In this chapter I explore the rationale for industry–farmer partnerships for wood production and describe different experiences in the Asia-Pacific region, using examples from the literature and from research undertaken with colleagues. The conditions for favourable partnerships are explored, the interests of different actors in the wood value chain are considered, and the benefits, disadvantages and risks of alternative partnership models are described. Key challenges include integrating multiple objectives in the partnership agreement, adapting to meet differing needs and dealing with uncertainties, such as changing market conditions and social objectives. I discuss the role of government in supporting these partnerships, and lessons for successfully integrating smallholders in wood-production value chains.

Historical forestry ownership structures

Much of the forest land around the world is owned by the state, which dominates forest ownership and wood markets (FAO 2020). For state-owned natural forests, the state has not incurred the cost of growing the wood and governments often make decisions on allocation and pricing of wood for reasons other than maximising short-term profits; for example, to encourage local industry development and employment. They incur costs of building and maintaining roads and other capital works for wood extraction, fire management and protection, and costs of controlling access and use of forests. These control costs are generally high for forests that are far from markets and administrative centres. In these locations, poor people often need to generate income by extracting resources from nearby forests (Hyde 2012). For forest plantations established on state land, the state has not incurred land costs. The costs of establishing and managing trees are often paid using consolidated revenue or through loans on favourable terms to forest agencies (Ferguson 2014). Given the large scale required for securing investment in manufacturing many types of wood products, only one or a few large processors may be present, with their manufacturing scale linked to available state wood resources.

State ownership and control of forests has resulted in varying quality of forest management. In developed countries, management has been relatively well regulated, at least from a state perspective (Scott 1998). In both developed and developing countries, rights or ownership of state forests have been allocated to large private actors to facilitate local industry development, often with the loss of traditional land-use rights and ongoing conflicts over access (Tegegne et al. 2018; Weiss et al. 2019). Lack of capacity to control state forests in developing countries meant they were often regarded as open access, common property resources and were unsustainably exploited and degraded. Governments have responded by engaging local people more in forest management decisions and by devolving control to communities, households or individuals (Agrawal et al. 2008). Allocation of forested land to households for agriculture, in response to political pressures by rural poor people, has driven forest exploitation and loss in some regions (Meyfroidt and Lambin 2011), while in other settings community and household management has proven important in maintaining or increasing forest area and quality (Hajjar et al. 2021). In some settings, for example in Indonesia, companies allocated rights to state resources have developed several types of partnerships with communities (Kurniasih et al. 2020).

As open-access forests have become degraded or converted to other uses, accessible wood resources have become scarce, increasing the cost of extraction and wood prices. This has created incentives for processors to buy land and invest in plantations or managed native forests, and for smallholder farmers to plant trees, or manage residual native forests to increase wood supply, for local use or for sale (Hyde 2012). These tree assets also represent a form of local bank that can hold value on site and be sold when other commodity prices are lower, or when additional income is needed (Baker et al. 2017). Wood trees planted in the right configuration can generate other tangible or intangible benefits – shade and shelter for crops and livestock, increased pasture productivity, reduced insect pests, soil protection, better water quality and aesthetic benefits (Baker et al. 2018; Jama et al. 2006; Nuberg et al. 2009).

The forest ownership structures described above have led to market imperfections that hinder small-scale tree growers from selling into established wood markets. They need to deal with oligopolies (few buyers and sellers of wood) and the resulting power imbalances and information asymmetries. Compared with markets for agricultural commodities, in which they participate at least annually in competitive local markets, they sell wood only occasionally, in relatively small quantities. Wood quality requirements are often unclear and pricing is not transparent. For their part, industrial wood processors incur high transaction costs in communicating, dealing with and coordinating the actions of many small-scale tree growers.

Smallholder-owned and family-owned forests produce a significant share of industrial wood in a range of settings, including Scandinavia, Japan and South-East Asia (Hull and Ashton 2008). In supplying wood to a market, small-scale growers are providing a service (growing trees) to large-scale wood-processing firms whose structure presents barriers to market competition and entry. Various arrangements have developed to overcome market imperfections inhibiting smallholders from participating in wood value chains. Tree grower cooperatives have operated successfully in many parts of the world for some time (Hull and Ashton 2008). Cooperatives give groups of farmers scale in the market, increase their bargaining power and reduce transaction costs for buyers because they only need to deal with one agent operating on behalf of the group. Cooperatives have established nurseries for seedling production, they own machinery for site preparation, and they enable bulk purchase of fertiliser or other inputs. In some places, cooperatives have become vertically integrated, pooling funds or raising capital to establish processing facilities (Elwood 1992).

Options for increasing wood production

Wood processors and tree-growing corporations wishing to expand their wood supply generally have 3 options (Keenan et al. 2019):

- Increase production from existing forests by intensifying their management.
- Buy or lease cleared land and employ more staff to manage and grow trees.
- Engage with rural landowners to encourage them to grow more trees for wood.

The first 2 options are problematic for commercial enterprises. Intensifying management requires investment in technology and research and has significant time lags between investment and return. Buying land involves significant capital costs, and land in desired locations may enter the market only sporadically making it difficult to build a consolidated estate. Social and political reaction to large-scale transformation of land use from agriculture to forest also imposes limits on purchasing rural land for growing wood (Brand 2019). The third option – engaging with landowners – allows wood processors to benefit from the increased use of land for tree growing and increase longer-term wood supply.

In the right locations and with the right technical knowledge, small-scale tree growers can, theoretically, be more efficient wood producers because they are better able to manage production risks and can use their portfolio of land and labour resources more efficiently, with reduced management overheads (Byerlee 2014). However, the industrial company also needs to consider longer-run issues, such as the overall volume, security and price of suitable quality wood to supply a capital asset. Investors in pulp mills, sawmills or plywood plants need to be assured that sufficient resources are available at a given price to justify investment in those production facilities. Transaction costs in dealing with many small suppliers of wood need to be considered in the investment decision.

The cost of land is a key factor. If enough land is available for purchase at the right price, then the decision to purchase is relatively easy, but this is often not the case. Community relations and social factors can be important factors in decisions about land purchase versus partnerships. Engaging in partnerships with rural landowners may be more politically and socially favourable, outweighing other costs associated with purchasing land. These industry–farmer partnerships can take a variety of forms – land leases with an annual rent, joint ventures, or farmers contracted as out growers to supply wood.

From the farmer's perspective, it makes economic sense to participate in these partnerships if the returns (both tangible and intangible) are higher than the costs, and higher than the returns from alternative uses of the land. Many farms have areas that are marginal for agricultural production and better suited to growing trees. Integrating trees may have benefits for farm production by, for instance, providing shade and shelter for livestock and crops. Lease payments or cash flow from sale of trees can diversify household income and provide revenue when agricultural returns are low or unexpected expenses occur (Baker et al. 2017). To make these partnerships work, considerable social, cultural and design challenges need to be addressed.

Varied pathways to contemporary forestry

In determining how to best integrate wood trees we need to consider the different social, cultural and economic circumstances in different countries. Australia, Vietnam and Laos have each taken different paths to developing tree-growing and wood-processing industries, and these are described below.

Australia

Australia is a modern, advanced economy with a population of 26 million people. It has the world's sixth largest area of forest (National Forest Inventory Steering Committee 2019), comprising 132 million hectares (ha) of natural forests and 2 million ha of intensively managed plantations covering 17% of the total land area. First Nation peoples have managed Australian landscapes for over 65,000 years, skilfully using fire and other land management practices to optimise habitat and landscape function for preferred species. These First Australians held traditional, customary rights over land, rights that were ignored following the British invasion in 1788, when land came under the control of the British Crown (Banner 2005). They were exterminated, removed or excluded from most of their lands and marginalised in society. Following Federation in 1901 (whereby the 6 self-governing colonies formed a union of states under a central federal government), land allocation and ownership continued as a state responsibility.

Early European settlers took land and, later, states allocated significant areas of forest to private interests for agriculture, most of whom felled these trees to make way for crops or pastures. Forests were also extensively cleared by mining operations and by governments for infrastructure and urban development. As forest resources became depleted, state forest agencies were established between 1880 and 1920 to protect remaining forest resources and regulate wood harvesting and other forest activities. Most farming land is now either privately owned, or managed under long-term Crown leases for grazing or other rural land use. Indigenous native title was finally recognised with the Mabo decision of the High Court in 1992 and the *Native Title Act 1993* came into effect on 1 January 1994. A report in 2021 indicated that native title (in full or part) was held over more than 40% of land area and exclusive-possession native title and freehold, which confer the right to exclude others from the land, is about 26% of Australia's land area (Nicholas 2021).

Concern about depletion of forests with unrestricted clearing raised interest in intensively managed plantations from the 1900s to restore forest cover and meet demand for softwood building wood. This process accelerated following World War 2 due to concerns about wood security, with the federal government providing loans to the states to establish about one million ha of mostly exotic softwood species (*Pinus* spp.). These softwood plantations now provide the bulk of raw material for construction wood, engineered products, panels and paper. Most of them have been sold by the states to private interests and are now managed by entities on behalf of local and international investors.

In the 1990s, governments sought to increase private investment in plantations (Jenkin et al. 2018). New tax arrangements provided for individuals to invest in plantations through companies buying agricultural land and operating managed investment schemes (MIS) on behalf of multiple investors. This popular investment mechanism resulted in almost one million ha of new hardwood plantations, primarily grown on short rotation for export woodchips.

The model was dependent on finance that dried up during the global financial crisis between 2008 and 2010. MIS companies went into liquidation, plantation assets were sold, primarily to international interests, and individual investors received only a proportion of their original stake (Ferguson 2014). These plantations are being harvested, mostly for export woodchips which are generating good returns for current owners. However, the area is declining as some areas are converted back to agriculture after harvest.

Overall, wood from plantations now supplies about 80% of wood used by domestic wood processors. In 2019–2020, significant areas were affected by extensive bushfires, reducing short-term wood supply capacity (ABARES 2022). Demand for wood products in Australia continues to grow with an expanding population. Supply from natural forests has fallen due to community demands for more areas to be protected for conservation. With imports of wood products increasing, the wood industry and the federal government have set a goal of 400,000 ha of new plantations by 2030 (AFPA 2016), but few new areas have been established. Competition for agricultural land is now high. Rising commodity prices and increasing land values make it challenging for investors to commit capital to new (greenfield) plantations with less certain and longer-term returns than agricultural commodities. To access more land for tree growing, Australian wood processors and plantation managers are showing interest in partnership models with farmers, which integrate trees into farms (Keenan et al. 2019).

Farm forestry has been the focus of policy attention since the 1980s, with investment in research, grants and provision of information. However, only a small area of trees has been established on farms specifically for wood production (Whittle et al. 2019). Policy support has not been well targeted and farm wood trees have often become stranded assets, in small or inaccessible areas or of tree species not saleable in current markets (Jenkin et al. 2018).

Vietnam

A single-party state, Vietnam has a population of 97 million and uses a mixed economic model in which decision-making occurs in a structured hierarchy, flowing from national to provincial and local governments. While climatically suitable for forests, the country's forests shrank to 28% of the land area during decades-long conflicts with France and the United States. With the victory of the Communist Party in 1975, all land became the property of the state. 'Market socialism' associated with the 1986 Đổi Mới economic reforms allowed farmers to lease land and to sell crops privately, and forest land was allocated to households or individuals for long-term forest use. Households could exchange, transfer, inherit, lease and mortgage land-use rights (Dang et al. 2019; Do and Le 2003). Under these reforms, the forest sector has transitioned from being under strong state control to becoming increasingly dominated by large-scale and small-scale private actors. In response to local community pressure, the government continues to allocate land from state forest companies to households for tree growing, but there are concerns about the mechanisms and transparency of land allocation processes.

Government reforestation efforts increased forest cover to 14.6 million ha (46% of the land area) with 4.32 million ha of planted forests. These programs aimed to increase rural income, support forest industries and improve the natural environment. As a result of this support for reforestation and ready access to growing markets for wood products in Japan and China and around the world, commercial plantation forestry and manufacturing of wood products have boomed. Vietnam is the world's largest exporter of hardwood chips (Nambiar 2020) and the fourth largest furniture exporter (Tham et al. 2021). Much of this supply is produced by smallholder tree growers, with 300,000 families managing areas of between one and 5 ha and contributing between 50% and 60% of domestic wood supply (Huong et al. 2020).

Producing wood is attractive for household tree growers because it requires relatively little cash outlay and family labour can be used to prepare the site and grow trees. The large number of households imposes significant transaction costs on those involved in supply chains. The market relies heavily on traders as intermediaries who provide important services such as organising harvest, transport and markets (Maraseni et al. 2017). Most of the harvesting and transport to the road is done by hand. Traders employ local people for harvesting and transport.

Australian *Acacia* species dominate commercial wood production (Nambiar 2020) due to their wood properties, ease of establishment and growth rates on degraded sites. Household growers typically plant trees at a high stocking rate (2,500 to 3,000 stems per ha) and harvest after 4 to 6 years. Returns may be higher for larger logs (Maraseni et al. 2017a) and some growers with larger holdings and more financial capacity are growing trees with lower stocking rates to a larger size over rotations of 6 to 10 years.

Generally, the demand for hardwood woodchips for export has provided smallholder farmers with quick returns for their forestry land (Blackburn et al. 2020) and little incentive to grow larger logs. Government has begun to implement policies to encourage growers to shift to longer rotations to produce sawlogs for furniture (Nambiar 2021; Huong et al. 2014), as the rapidly expanding furniture industry relies on imported logs for up to 80% of its wood (Blackburn et al. 2020). The uptake has, however, been limited. Stronger linkages between wood processors and smallholder tree growers could potentially address this challenge (Keenan 2019).

Laos

Laos is Vietnam's neighbour to the west, with a similar land area, but much smaller population of 7.2 million. The political structure and land ownership arrangements are similar – a single-party state that owns and controls land. Current forest area is 13.2 million ha (57.5% of the land area). Significant forest areas in central and southern Laos were heavily degraded during the American war in Vietnam, which spilled into Laos. Following the establishment of the Lao People's Democratic Republic in 1975, and the adoption of *chintanakan mai* (New Thinking) and the New Economic Mechanism in 1986, forest policies aimed to stimulate investment in tree plantations by local people and foreign enterprises, and encourage a domestic wood-processing sector for local and export markets, along with positioning the forest sector as a contributor to broader national socioeconomic and environmental objectives (Smith et al. 2021).

During the 1980s, farmers planted teak on suitable sites in northern Laos and international donors supported research on several tree crops. Under national polices, tree growing allowed farmers to secure and retain access to land, and absentee landowners could use planted trees to demonstrate their ongoing use of land. In this period, the government responded to global environmental concerns about forest cover loss and, at the first National Forestry Conference in May 1989, committed to achieving a forest cover target of 70% by the year 2020. A program of allocating land and forest to households, and the granting of land through concessions and leases to companies, especially to foreign investors, aimed to 'Turn Land into Capital' with only 'degraded' or 'barren' forestland allocated for plantations; the rationale being that plantations of commercial, fast-growing species could bring this degraded land back into productive use (Smith et al. 2021).

Released in 2005, the Forestry Strategy to 2020 included a target of planting up to 500,000 ha of trees to contribute to the national target of 70% forest cover, alleviate pressures on remaining natural forests, supply wood to the emerging domestic processing and export industries, and support stable income and employment options for farmers engaged in shifting cultivation. Large-scale investments were enabled to take over state land, leading to concerns over how approvals were granted and their impacts on, and lack of benefits for, local communities and the environment. The Prime Minister's orders suspended concession approvals in 2007 and again in 2012. Over the following 10 years, new commercial tree-growing concessions and leases on state land have been limited due to the challenges of foreign investors engaging with local communities to access land (Smith et al. 2021).

The current wood plantation area is 214,000 ha. Smallholders own 99.3% of teak plantations, which are mostly in northern Laos, whereas foreign investors own 88.3% of eucalypt and acacia plantations, mostly in central and southern regions, with smallholders under contract farming arrangements owning 10.4% (Smith et al. 2021).

Laos offers several comparative advantages for investing in tree plantations, including its geographic location, rapidly improving regional connectivity and the extent of potentially suitable land. In general, policies to support plantations have lacked a clear vision, sufficient detail, a common understanding of accountability and the capacity to bring them into effect. A tension exists between the desire to attract foreign investment for national development and the need to resolve land ownership and allocation arrangements in a way that provides security of tenure for rural households and a firm basis for their role in land-based production.

Analysis of partnerships in commercial forestry

Research projects I have been involved with have focused on assessing the conditions under which partnership models between commercial forest-product firms and farmers and rural landowners might generate beneficial outcomes for both parties, and for others along the wood supply chain. Our research was guided by the Sustainable Livelihoods framework (Scoones 1998). We analysed supply chain and financial impacts and barriers to smallholder and industry investment in a) woodchips and wood in Vietnam and b) teak furniture production in Laos (Keenan 2019). Seven research sites were selected. These sites spanned 5 plantation models, including smallholder-led short-rotation and longer-rotation acacia plantations in central Vietnam and private-company-led short-rotation eucalypt plantations in Laos. Some private-company-led plantation models aimed to integrate community demand for land to grow rice and cash crops with company interests in trees for wood, contracted outgrower arrangements and leasing of village land. We also analysed the effects of government regulation on tree growing, incentives for plantations (including longer rotations or higher value production), provision of extension, technical support, access to finance, and risk management. In Australia, our research involved surveys to assess attitudes to tree growing and industry partnerships (Keenan et al. 2019).

The ingredients of a successful partnership

Our results indicated that successful industry–farmer relationships can be built based on:

- equitable benefit sharing
- genuine partnerships
- strong value chains along which information, resources and value are shared.

These success factors, which are discussed further below, can be linked in partnership models that incorporate 5 elements (Byron 2001):

- **Land** – Needs to be capable of growing the desired tree species at an acceptable rate; within an economic distance of a mill or port; be accessible to harvesting machinery and transport; and be large enough in area to ensure a viable harvest volume.
- **Capital** – Pays for land costs and establishing and maintaining the trees until harvest. In some cases, governments may contribute funds through grants or payments for tree growing by a company, landowner or third-party investors. Grants or payments linked to benefits such as carbon sequestration or water quality can improve the overall return on investment and make investment more attractive by providing income while trees are growing. Grants and payments should be geographically targeted and performance-based, and should consider all negative and positive impacts.
- **Labour** – Consists of the human input to plant and manage the trees. It can be provided, or paid for, by the company, the lwandowner, or a third-party contractor.
- **Technical package** – Specifies the commercial tree species with growth, form and wood properties resulting from breeding and improvement, and includes site knowledge and management requirements. A science-based package reduces risks of adverse site selection or poor tree growth and underpins value by producing wood with known market properties.
- **Market** – Can be an agreement with a wood buyer to purchase wood (an offtake agreement), which gives landowners, and third-party investors, confidence in the future market. The purchase agreement can be based on a set future price or linked to a market index such as export prices. It can be 'take-or-pay' or 'first right of refusal'. The latter allows tree owners to sell to another buyer offering a higher price, but the party to the agreement gains the right to buy at the higher price.

In a report on partnership models in Australia in which a landowner provides land, Keenan et al. (2019) recommended that the following aspects be considered in agreements:

- the source of capital (a company, an independent investor or the landowner)
- the nature and timing of payments to landowners
- inputs by landowners
- ownership of the trees
- who receives payments for services such as carbon sequestration
- the landowner's exposure to market risks.

These partnership models can apply to short-rotation or longer-rotation softwood or hardwood plantations. Flexible configurations of trees on the land are possible (wider windbreaks, strips, areas around irrigators or in larger blocks).

The agreement underpinning the partnership

The partnership model is underpinned by an agreement that describes:

- the time frame
- lease payment and cost or profit-sharing arrangements
- responsibility for rates, taxes or insurance
- condition of land at the end of the agreement (for example, who is responsible for the stumps and site clean-up)
- transfer rights, treatment of carbon or other obligations
- consultation and grievance arrangements
- termination, review and renewal
- compliance with relevant legislation, planning or forest certification requirements.

The agreement also needs to cover risks such as bankruptcy of either party, plant closures or major changes in market conditions. Government can provide underwriting or insurance arrangements, as it does it other sectors, such as construction. Management activities and responsibilities can be attached to the agreement. Other ingredients for success are shown in Figure 15-1.

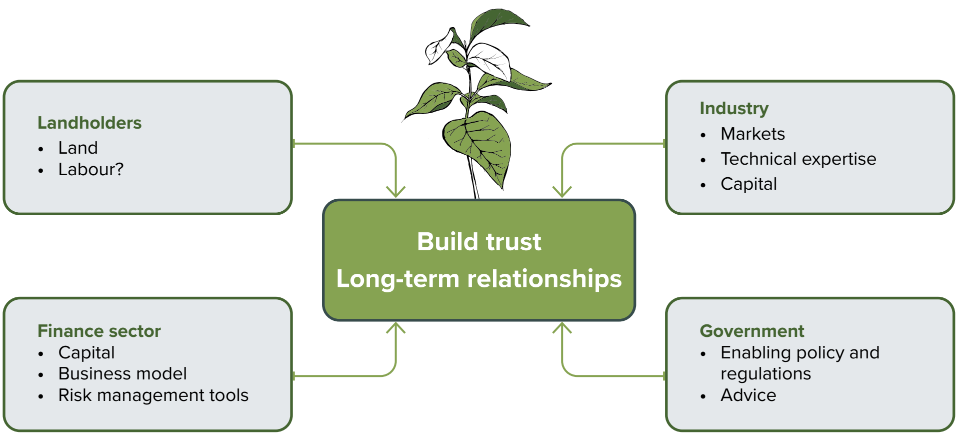

Figure 15-1: Ingredients for successful industry–smallholder relationships

Equitable benefit sharing

Partnerships for wood production can generate tangible and intangible benefits. Tangible benefits include cash income and increases in physical and human capital. Intangible benefits include environmental and social benefits.

Cash income

Studies in all 3 countries (Australia, Vietnam and Laos) indicate that growing trees for wood can be relatively profitable, depending on the market price for wood and the discount rate applied to future income. Surveys in Vietnam indicate that households clearly benefit from investing their time and financial resources in tree plantations. Buoyant woodchip markets are generating significant household economic, social and wellbeing benefits and broader benefits for regional economies. Almost all (90%) tree growers surveyed said they were better off than 5 years before, with 82% indicating incomes from wood plantation as the main reason for livelihood improvement. Increased savings from selling wood was considered a key food security strategy.

In Vietnam, households and state forest companies are important players in the wood market and households also receive income from wood sales and from wage labour working for state companies. In the 5 years before the survey, the sale of plantation wood provided over 5 million Vietnamese dông per year (US$217 per year per household), or 25% of the total annual household income. This much again was generated in wage income in state plantations, though this work was seasonal, irregular and available at times when labour was required for planting, tending and harvesting. These benefits, however, take time to realise. Of those surveyed households who had recently invested time and money in trees, 12% had experienced a decline in livelihood because of the initial costs of seedlings, soil preparation and early management.

In Laos, agroforestry production models demonstrated positive net present value (NPV) using a discount rate of 12%, with internal rates of return ranging from 16.7% for eucalypt–cassava to 20.1% for the eucalypt–rice intercropping model. Where households had few alternative income opportunities, plantations could significantly increase household cash income, with payments from land lease fees, labour, company livestock and other programs contributing between 26% and 64% of the total household income (van der Meer Simo et al. 2019; Barney 2024). Households in these villages were generally supportive of allocating more land to plantations, but the company was restricted by hold-ups associated with provincial government approval of lease arrangements.

In contrast, in a village in Savannakhet Province, where the Indian company Birla Lao Pty Ltd aimed to secure 50,000 ha of land for plantations, households benefited more from financial remittances from village youth working elsewhere and from livestock and rice sales than from engaging with the company, which offered only labour income, providing just 2% of average household income. Consequently, this company had limited success in securing land and it sold its interests in Laos. In another part of this province, contract tree-grower arrangements set up by a Japanese company have also been problematic. The company provided seedlings and initial support, but the market for the wood was limited and 63% of villagers who planted trees failed to sell them (van der Meer Simo et al. 2019).

Furthermore, when looking across the wood supply chain, it is often the case that most of the value (profit) currently accrues to the product manufacturer. For example, in a study of a teak value chain in Sainyabuli Province in Laos, Maraseni et al. (2018) found that teak logs for furniture manufacturing generated profits for growers (from US$8.40 to US$23.30 per m^3 of final product), middlemen (US$4.70 per m^3 of final product) and the furniture manufacturer (US$171 per m^3 of final product).

Companies seeking partnerships need to recognise the desire for villagers as a collective, or as individual landowners, to continue agricultural production. In Australia, 55% of surveyed landowners were willing to plant trees for commercial harvest on up to 10% of their land. Only 17% were willing to consider planting trees on more than 20% of their land. This can be part of a strategy within the community or family to maintain a diversified livelihood portfolio. The implication for companies is that they will have to manage smaller areas of trees on multiple properties. Potential for additional financial benefits from tree growing, such as carbon credits, can increase landowners' willingness to consider planting trees for commercial harvest. Companies can facilitate access to such environmental services income by acting as project developers and aggregators on behalf of groups of smaller landowners. They can also support activities to quantify the on-farm benefits associated with increasing trees in the rural landscape.

Forest certification can add value to wood production by demonstrating to consumers the sustainability of wood production used in products they consume and giving growers access to higher value product markets. However, a study of an acacia supply chain in Vietnam (Maraseni et al. 2017b) indicated that, while certification may increase the return on wood for growers, much of the higher market price goes to the processors because they directly interact with the market. On the other hand, the tree growers bear most of the cost of meeting certification requirements and having their operation audited. Industry partners can play a role in developing grower cooperatives to reduce the costs of audit and compliance for individual growers.

Figure 15-2: Wide-spaced eucalypts and rice grown by local villagers in plantations developed by the Stora Enso Company in Savannakhet Province, Laos

Credit: Rodney Keenan

Other benefits

Our studies indicated that household benefits of tree plantations extend beyond cash income. In Vietnam, households reported improvements such as new or renovated houses, payment for children's education, ability to afford other daily necessities and greater financial security, reducing stress and worry. This was partly due to government policies to provide secure land ownership for tree growing, which underpinned access to finance, and thereby created a family asset to hand on to future generations. These policies had positive psychological effects – they gave hope for a better future, they enhanced self-esteem, confidence and social status, and they reduced the migration of young people to urban areas. Development of plantations by smallholders improved social capital through sharing knowledge and experience among community members; offering mutual support during crises, such as loss of plantations due to natural disasters; and contributing to social events in the community.

In Australia, our research indicated that beliefs about the wider benefits of planting trees vary among farmers and these beliefs affect their intentions to engage in potential partnerships with the wood industry to grow trees. For example, they differed in their views on the capacity of trees to provide multiple environmental, social and economic benefits; on the importance of maximising income and returns from the land; and on the extent to which commercial forestry is compatible with current land uses. Recognising and addressing these beliefs is an important factor in encouraging farmers to engage with wood markets and partner with industry. Partnership models should clearly demonstrate the 'relative advantage' of forestry to landowners. In designing tree plantings to enhance on-farm and environmental benefits of commercial plantings, companies need to accommodate these varying beliefs to align the partnership with landowner requirements, including the structure of cash flow and overall financial returns.

Genuine relationships

Enduring partnerships built on genuine collaboration and equitable sharing of benefits can promote vertical and horizontal linkages in the wood value chain. Eroded trust, lack of transparency and accountability and poor communication are key barriers to these partnerships. In Vietnam, the strong demand for wood and the profitability of tree growing mean that partnerships between smallholders, state enterprises and the wood industry can alleviate poverty. Similarly, in Laos, investment in tree plantations can be an effective vehicle for partnerships between government, industry, investors and the community.

Community attitudes towards industry partnerships are influenced by prevailing attitudes and beliefs, reinforced by company practices. For example, the plantation program implemented by Stora Enso Ltd in Laos involved extensive community consultation, participatory land-use planning, compensation for land, and investment in community development. Nevertheless, villagers were still hesitant about committing significant land areas to tree growing, perhaps because they preferred a more risk averse 'subsistence livelihood ethic' or they expected land value to increase in future and, therefore, committing land to trees under long-term agreements could mean foregoing future opportunities for the use of land (Van Der Meer Simo et al. 2020). Other companies lost trust by clearing natural forest for plantations without consulting or engaging the community in participatory planning. In these cases, many villagers lost informal access to forest land for grazing or other uses, and a significant number of households reported being worse off, with a majority disapproving the companies' approach (Van Der Meer Simo et al. 2020).

Our research on landowners' attitudes to tree-growing partnerships in southern Australia indicated that understanding landowner beliefs and motivations can be used to tailor tree establishment and growing models. Differences in dominant beliefs are, however, not readily distinguished by sociodemographic or land-use characteristics. All landowners, regardless of beliefs, want active involvement in initial planning and decision-making, a clear statement of financial outcomes, and a plantation design that provides environmental and on-farm benefits. As in Laos, it is crucial to involve landowners in decision-making on commercial trees – such as where to establish the trees, what planting configuration to use, and which species to plant – and to recognise their need to access the land once the trees are established. Flexible planting design and management models can align different goals and objectives of individual landowners. Educating and working with local farming community leaders and agricultural advisers can build on the trust already developed by these advisers. Transparency in the provision of market information, tree growing risks and any contingency planning can reduce uncertainty for the landowner. Research to improve understanding of community attitudes and beliefs about trees and motivations for managing land can, therefore, be valuable in designing successful tree-growing models.

Done well, partnerships with landowners can give the wood industry more access to land for less initial capital outlay, diversify sources of wood supply, and demonstrate wider benefit sharing from their investments. To achieve this, investors need to set clear goals and targets to inform stakeholders of company plans and frame their targets and goals in terms of the benefits, desired outputs and outcomes that the community want. This can include increased wood supply, regional investment, jobs, improved water quality and conservation. Such partnerships require a shift from traditional transactional negotiations, focused on minimising costs for industry, to long-term relationship building, with partners explicitly revealing preferences and interests and working together towards a shared long-term vision. Models need to be flexible to meet different landowner needs, including in payment arrangements, landowner co-investment, and tree location and design on farms. This can include permanent plantings for shade, shelter, aesthetics or biodiversity benefits as well as areas of commercial trees.

Strong value chains

Equitable benefit sharing and genuine long-term relationships can be built into value chains that increase value for all actors. Even simple communication arrangements can be effective. For example, in Vietnam, having direct communication with the factories allows tree growers to check prices and take advantage of increased market price. Improved value-chain arrangements can also support growers to produce higher value products. Tree growers in Vietnam can receive greater returns by growing logs to a larger size in longer rotations. However, they need to wait an additional 3 to 5 years for income. Most growers are small scale, with a strong preference for more immediate income to pay off loans or meet household expenses. Some high-income households can delay the harvesting of longer-term plantations, but their decisions are influenced by lack of knowledge, lack of access to price information, and their perception of risks of losing trees to typhoons, which are common in the region, or to disease.

Bigger sawlogs also require investment in specialised heavy machinery for harvesting, loading and transporting logs from the forests, as well as in the receiving sawmills. Bottlenecks at various stages of the forestry value chain (contracting terms, chain linkages and transparency in distribution of cost and benefit among members of the chain) discourage this investment. Seedlings with improved genetic material can increase growth and wood quality but, in central Vietnam, despite the availability of these seedlings from state-owned companies or research centres, villagers tend to buy from local nurseries due to their proximity, close relationships and lower price.

Intermediaries and traders are often regarded as problematic actors in wood supply chains, but our studies revealed that they play important and necessary roles, especially for growers. In Vietnam, more than 80% of smallholder wood is sold to traders and the rest direct to factories, the latter mostly being from growers with a large land area and their own harvesting equipment. There is a need to support the roles and skills of intermediaries and traders and reduce their costs of compliance with government regulations.

The wood processing industry can address these challenges, and generate better-quality logs and more profit, by offering and advertising increased price premiums for larger logs, supporting growers to use better-quality seedlings and silviculture to improve log quality, and providing credit. They could support traders to acquire suitable harvest and transport equipment.

Figure 15-3: **A smallholder plantation of an acacia hybrid in central Vietnam, thinned to produce larger logs**

Credit: Rodney Keenan

Figure 15-4: **Scansia Pacific Ltd, a furniture plant in central Vietnam, processing an acacia hybrid grown by smallholder farmers**

Credit: Rodney Keenan

Overall, in the 3 places studied (Australia, Vietnam and Laos), relationships along wood supply chains were poor. Creating a genuine value chain with more information on product quality, finance arrangements, risk management and general collaboration along the chain could increase total wood output and value, and drive efficiencies in production and processing.

To encourage more farmers to grow trees for wood, processors could offer financial incentives to support certification and improved management, and give farmers access to credit, insurance, marketing and advice.

In Australia, landowners supported 3 broad investment models:

- **Independent** – The landowner is responsible for establishing and managing the trees, pays all associated costs and receives all, or a share of, the net proceeds at the time of sale.
- **Third party** – A commercial partner is responsible for and pays all costs associated with establishing and managing trees, with the landowner receiving an annual payment or a share of the net sales proceeds at the time of sale.
- **Shares** – Responsibility for establishment and management is shared between the landowner and a third party. Payment arrangements vary depending on the arrangements and agreement with the third party.

The 3 models essentially differ in the degree of risk borne by the landowner. All 3 models are acceptable to a greater or lesser degree, highlighting the need to match business models to the tolerance for risk, as well as to the goals and objectives of individual landowners.

Figure 15-5: Eucalypt wood trees sheltering sheep on a farm in south-west Victoria
Credit: Hugh Stewart

Role of government

Government can play a key role supporting a policy environment that facilitates rather than constrains plantation development, enabling incentives such as information, research and infrastructure, support for networks and value chains, and targeted financial support and incentives. This includes allocating, zoning and land-use planning to support tree plantations.

In Vietnam, government allocation of land to households for tree growing has been a long-term contributor to the success of plantation wood production. However, with the increased householder demand for land, dissatisfaction has risen, according to our surveys, due to inconsistent and complex procedures for acquiring 'red books' as certification for long-term ownership; lack of transparency and lack of grievance mechanisms; and lack of opportunity to be involved in land allocation processes. Despite regulations stipulating involvement of local communities in forest land allocation decisions, only half of survey respondents were engaged in land inventory and demarcation in the field and less than 37% were informed about, or involved in, local meetings about land use and land allocation. Ethnic minorities had a particularly low level of awareness on the amount and location of land being allocated. District and provincial administrators reported that these problems are due to inadequate finance and human resources allocated to planning. These problems are eroding trust in local authorities and causing conflicts between smallholders, state forest enterprises and authorities.

Inequity in land allocation processes means that benefits are unevenly distributed between communities and households. Some 'early mover' households in Vietnam secured larger areas (more than 10 ha, some more than 20 ha) to grow trees. More recently, households have been allocated smaller areas (3 to 4 ha), while ethnic minority groups, who have less power and fewer networks with administrators, have been allocated an average of 1.7 ha and some as little as 0.4 ha. The relationship between the size of household landholding and total annual average income is strongly positive. A high-income household with an average of 7.9 ha of forestland earns 10 times more than a lower-income household. Strengthening accountability and trust in institutions is crucial. Mass organisations (such as the Women's Union and the Youth Farmers Association), with their extensive networks at the local level, can play a role.

In Laos, our research found that local land-use planning is neither well-coordinated nor inclusive, and the principles for allocating land to corporate investors or smallholder tree growers are not clear. The interaction and coordination between levels of government and across different government agencies responsible for plantations and processing is weak and inconsistent. Regulations for establishing, managing and harvesting plantation wood are largely based on control mechanisms for natural forests. While there has been some reform for plantation wood, there are still high regulatory and transaction costs associated with establishing and harvesting forest plantations.

In Vietnam, consistent, long-term policy has provided a strong enabling environment, but in Laos and Australia the lack of a clear policy covering plantation development creates uncertainty for all investors. In Laos, investment procedures for foreign investment in plantations have been uncertain. Complex and inconsistent, government agencies largely act as a gatekeeper and fee collector, rather than facilitating investment in a partnership arrangement. Consequently, while plantations have good economic potential, this potential will only be realised through planning, promotion and partnerships.

Identifying strategic investment zones for tree plantations and processing facilities, then aligning agency responsibilities to support these zones, could guide private and government investment in plantations. Developing plans for regional investment hubs will require industry leadership and regional platforms for inclusive consultation with stakeholders along the forest-sector value chain, in local government and in the broader community. By collaborating across the sector, the industry could develop and present consistent messages about the opportunities for investors, along with the potential co-benefits (for farm production and biodiversity, for example) that could build public support for the sector. Companies need to clearly communicate what commercial species they want to see planted and why, the minimum areas for viable planting, the required management and an indication of prices, harvesting and transport costs.

Local governments play a critical role in planning, regulating and approving commercial tree growing on private land. They provide and maintain local infrastructure, such as roads and bridges. They could be strong advocates of investment in commercial tree plantations on rural land – if the right models were in place with strong community support. They can play a facilitating role by incorporating commercial trees into planning schemes, providing a clear right to harvest. To do so, they need appropriately trained and informed staff to manage codes of practice for commercial trees.

Government policy can support collaborative partnership models by improving landowners' negotiating power through access to information and by supporting cooperative tree-grower organisations. Information needs include market trends, product prices, calculation of returns and risk assessments. Governments could also develop standardised legal agreements or underwrite investment risks.

Governments can facilitate knowledge exchange (via both formal and informal channels) and build farmers' capacity for tree growing. Training needs to focus on practical content, such as selecting quality seedlings, detecting and managing pests and diseases, improving harvesting and management, financial management and product marketing. Educating and working with rural advisers on tree growing models would also support engagement of farmers in collaborative partnerships with industry. Governments can also play a role in supporting planning for increasing climate risks along the value chain. In particular, investing in research to test and confirm species and products from dryland regions could open a wider area of land for commercially attractive tree species and wood products.

Conclusions

Prevailing ideologies in wood production often favour large-scale investment in technology and machines, standardised tasks and processes, hierarchical, 'scientific' management and spatial orderliness over messy, diversified smallholder rural production (Byerlee 2014). Our studies indicate that partnerships between rural landowners, wood processors and investors can successfully link both models, given the right conditions. Increasing standards for social and environmental sustainability in global markets are further driving demand for partnerships between smallholders and responsible wood-processing companies.

A business model represents how a company structures its resources, partnerships and customer relationships to create and capture value – that is, to generate income. Successful models are those in which the benefits outweigh the opportunity costs for all partners. Business models are collaborative when they involve close working partnerships and share value by creating value for both the company and the partners; for example, local landowners and suppliers. An effective business model for wood products therefore involves all people in the value chain. Tree crops require longer timeframes to generate returns than most other forms of agriculture, with different risks and uncertainties. So, for example, if financial returns for farmers are modest, configuring trees on farms to provide more immediate on-farm benefits will make them more attractive to farmers while also meeting longer-term industry needs for wood.

Independent agents or brokers (perhaps funded by governments or non-government organisations) can bring industry and landowners together, informing everyone involved without having a vested interest in a specific agreement. Such agents need a clear understanding of what is mutually fair and realistic for all. Partnerships with responsible companies may help smallholder tree growers overcome disadvantages such as lack of access to markets, to technology and or to technical advice. Vertically integrated plantation companies can benefit from lower transaction costs involved with accessing land and labour. All partnership models should be based on sound financial analysis, good technical information and transparent agreements that clearly assign the ownership of different assets (land and trees) and should state the rights, responsibilities, risks and rewards for each party.

Partnership models will develop and evolve over time as companies engage and learn, and as landowners build knowledge of the benefits of commercial trees, and confidence in the processing sector. This evolution can be assisted by investing in organisations to support research and extension, by providing secure land title and by financial institutions supporting smallholders and farmers.

References

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) (2022) *Australian forest and wood products statistics Mar-Jun 2022*, ABARES, Canberra.

AFPA (Australian Forest Products Association) (2016) *Plantations: the missing piece of the puzzle*, a policy proposal for the Australian Government 2016 Budget, AFPA, Canberra.

Agrawal A, Chhatre A and Hardin R (2008) 'Changing governance of the world's forests', *Science,* 320:1460–1462.

Baker K, Bull G, Baylis K and Barichello R (2017) 'Towards a theoretical construct for modelling smallholders' forestland-use decisions: what can we learn from agriculture and forest economics?', *Forests,* 8(9):345.

Baker T, Moroni M, Mendham D, Smith R and Hunt M (2018) 'Impacts of windbreak shelter on crop and livestock production', *Crop and Pasture Science,* 69:785–796.

Banner S (2005) 'Why terra nullius? Anthropology and property law in early Australia', *Law and History Review,* 23(1):95–131.

Barney K (2024) 'Commercial timber plantations and community livelihoods: insights from comparative case studies in southern Laos', *Forest Policy and Economics*, 158:103099.

Blackburn D, Huong VD and Mendham D (2020) 'Returns to Vietnamese smallholder farmers from managing acacia plantations for sawn wood over 4-10 year rotations', *Forest Policy and Economics,* 121:102318.

Brand D (2019) *Transforming the forestry asset class*, New Forests, Sydney.

Byerlee D (2014) 'The fall and rise again of plantations in tropical Asia: history repeated?', *Land,* 3(3): 574–597.

Byerlee D and Rueda X (2015) 'From public to private standards for tropical commodities: a century of global discourse on land governance on the forest frontier' *Forests,* 6(4):1301–1324.

Byron N (2001) 'Keys to smallholder forestry', *Forests, Trees and Livelihoods,* 11:279–294.

Dang TKP, Van Der Zouwen M and Arts B (2019) 'Challenges of forest governance: the case of forest rehabilitation in Vietnam', *Public Organization Review,* 19:425–452.

Do D and Le QT (2003) 'Forest policy trends in Vietnam', in Inoue M and Isozaki H (eds) *People and forest – policy and local reality in Southeast Asia, the Russian Far East, and Japan*, Kluwer Academic, Boston.

Elwood NE (1992) 'Forestry cooperatives in Japan', *Journal of Forestry*, 90(6):25–28.

FAO (Food and Agriculture Organization of the United Nations) (2020) *Global forest resources assessment 2020: key findings*, FAO, Rome.

Ferguson I (2014) 'Australian plantations: mixed signals ahead', *International Forestry Review,* 16:160–171.

Hajjar R, Oldekop JA, Cronkleton P, Newton P, Russell AJ and Zhou W (2021) 'A global analysis of the social and environmental outcomes of community forests', *Nature Sustainability,* 4:216–224.

Hull RB and Ashton S (2008) 'Forest cooperatives revisited', *Journal of Forestry,* 106:100–105.

Huong VD, Nambiar E, Hai NX, Ha KM and Dang NV (2020) 'Sustainable management of *Acacia auriculiformis* plantations for wood production over four successive rotations in south Vietnam', *Forests,* 11:550.

Hyde WF (2012) *The global economics of forestry*, Routledge, New York, NY.

Jama B, Elias E and Mogotsi K (2006) 'Role of agroforestry in improving food security and natural resource management in the drylands: a regional overview', *Journal of the Drylands,* 1:206–211.

Jenkin B, Keenan RJ and Bull L (2018) *Tree plantation investment and partnerships in Australia: an analysis of past experiences – summary report*, Report 1 of the Next Generation Forest Plantation Investment research project, The University of Melbourne, Australia.

Keenan R (2019) *Improving policies for forest plantations to balance smallholder, industry and environmental needs in Lao PDR and Vietnam*, project final report, Australian Centre for International Agricultural Research, Canberra, ISBN 978-1-925746-78-5.

Keenan RJ, Anderson N, Bull L, Dembek K, Kostanski L and Patterson S (2019) *Designing business models for commercial tree-growing partnerships on rural land*, Report 9 of the Next Generation Plantation Investment research project, School of Ecosystem and Forest Sciences, The University of Melbourne, Australia.

Kurniasih H, Ford RM, Keenan RJ and King BJ (2020) 'A typology of community forestry approaches in Indonesia: implications for external support to forest communities', *International Forestry Review,* 22(2):211–224.

Maraseni TN, Son HL, Cockfield G, Duy HV and Nghia TD (2017a) 'Comparing the financial returns from acacia plantations with different plantation densities and rotation ages in Vietnam', *Forest Policy and Economics,* 83:80–87.

——(2017b) 'The financial benefits of forest certification: case studies of acacia growers and a furniture company in Central Vietnam', *Land Use Policy*, 69:56–63.

Maraseni TN, Phimmavong S, Keenan RJ, Vongkhamsao V, Cockfield G and Smith H (2018) 'Financial returns for different actors in a teak timber value chain in Paklay District, Lao PDR'*, Land Use Policy*, 75:145–154.

Mayers J and Vermeulen S (2002) *Company-community forestry partnerships: from raw deals to mutual gains?*, International Institute for Environment and Development, London, England, ISBN 1-899825-94-0.

Meyfroidt P and Lambin EF (2011) 'Global forest transition: prospects for an end to deforestation', *Annual Review of Environment and Resources,* 36:343–371.

Nambiar ES (2020) 'Strengthening Vietnam's forestry sectors and rural development: higher productivity, value, and access to fairer markets are needed to support small forest growers', *Trees, Forests and People***,** 3(2):100052.

National Forest Inventory Steering Committee (2018) *Australia's state of the forests report 2018*, ABARES, Canberra.

Nuberg I, George B and Reid R (2009) *Agroforestry for natural resource management*, CSIRO Publishing, Canberra.

Scoones I (1998) *Sustainable rural livelihoods: a framework for analysis*, IDS working paper issue 72, Institute of Development Studies, University of Sussex, Brighton, UK.

Scott JC (1998) *Seeing like a state: how certain schemes to improve the human condition have failed*, Yale University Press, New Haven, CT.

Smith H, Kanowski P, Keenan RJ and Phimmavong S (2021) 'Lao plantation policy: prospects for change', *Forests,* 12:1132.

Tegegne YT, Van Brusselen J, Cramm M, Linhares-Juvenal T, Pacheco P, Sabogal C and Tuomasjukka D (2018) *Making forest concessions in the tropics work to achieve the 2030 agenda: voluntary guidelines*, FAO Forestry Papers, FAO, Rome.

Tham LT, Darr D and Pretzsch J (2021) 'Analysis of Acacia hybrid timber value chains: a case study of woodchip and furniture production in central Vietnam', *Forest Policy and Economics,* 125:102401.

van der Meer Simo A, Kanowski P and Barney K (2020) 'Economic returns to households participating in different models of commercial tree plantations in Lao PDR', *International Forestry Review,* 22:132–152.

Weiss G, Lawrence A, Lidestav G, Feliciano D, Hujala T, Sarvašová Z, Dobšinská Z and Živojinović I (2019) 'Research trends: Forest ownership in multiple perspectives', *Forest Policy and Economics,* 99:1–8.

Whittle L, Lock P and Hug B (2019) *Economic potential for new plantation establishment in Australia: outlook to 2050*, ABARES research report 19.4, Department of Agriculture and Water Resources, Canberra.

Chapter 16

Revealing insights into smallholders' livelihoods and forestry in the tropics

Digby Race

Agroforestry across the tropical world

This book set out to illustrate the range of agroforestry practised across the tropical world, based on the extensive experience of researchers working with smallholders, and inspire with stories demonstrating smallholders' ingenuity and persistence. While many more examples of agroforestry exist, the book's focus is on the applied and innovative research occurring along the agroforestry continuum – from seed to market, across a wide range of pathways. It provides valuable insights from researchers working closely with smallholders and partner organisations to initiate and optimise agroforestry wherever it is established.

The broad definition of agroforestry adopted for this book is the 'purposeful integration of trees into farming systems'. Deliberately broad and inclusive, this definition is intended to avoid becoming bogged down in the semantics of scale, silviculture and species. It seeks to shift the attention to the decisions made by capable and knowledgeable smallholders for the 'purposeful integration' of woody vegetation into their farming systems. The social networks of smallholders seem to offer the ideal proving ground for adapting, developing and optimising new ideas and opportunities within their farming systems to best suit their personal context. Such bottom up, localised adaptations make each of the agroforestry examples in this book somewhat unique. Even among those who live in the same community, not all smallholders have the same aspirations and capabilities, so how to optimise an individual farming system is invariably personal.

Historically, the slower pace of mobility and communications meant farming communities were inevitably localised – in their knowledges and practices – with only occasional connections to outsiders. New ideas or observations of alternatives were filtered by a community's shared experience and preferences about how to optimise their livelihoods. Increasing human mobility and connectivity throughout the 20th and early 21st centuries has heralded unprecedented change, bringing both challenges and opportunities. Now, ideas from faraway places can stimulate new ways of thinking, leading to a more rapid evolution of local norms and practices.

While agroforestry in various forms has been practised for millennia, it holds a new relevance in the modern world as a means of building prosperous and sustainable farming systems. Indeed, agroforestry is increasingly recognised as a local practice that can build the resilience of smallholders' farming systems and livelihoods. As the Intergovernmental Panel on Climate Change (IPCC) recently confirmed, the rate and scale of humanity's response to the clear signs of the planetary system under stress – if not the early stages of collapse – demands a marked acceleration in adaptation (IPCC 2021, 2022 and 2023). Agroforestry is a potential solution that can be defined locally and scaled up globally.

Global agendas, local action

Building on earlier agendas and initiatives, the United Nations Sustainable Development Goals (SDGs) outline the multidimensional nature of sustainable development, with targets to be met by 2030. Agroforestry as practised by individual smallholders and in aggregation at a community level can contribute to achieving the SDGs; for example, SDG 8 on inclusive and sustainable economic growth; SDG 13 on reducing the impacts of climate change; SDG 15 on promoting sustainable land use. Finding ways to better balance economic development and environmental sustainability has been increasingly highlighted by the IPCC and leading scientists for more than a decade. The regular United Nations climate change conferences (most recently, COP28 held in December 2023) have also proven central to bringing about a shared understanding of the profound challenges we face and the global commitments we need to finding ways to build prosperity without harming nature.

In 2008, the United Nations established the Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. This UN-REDD Programme has managed over US$1 billion from sponsoring countries to foster a change in government policies and landscape-level projects in over 60 countries. Under the program, over US$350 million in payments has been made to local communities, who have demonstrated a positive change in forest and landscape management. Another global initiative, the Green Climate Fund, was established in 2010 with the agreement of 194 countries, with over US$10 billion already committed to supporting low-emission and climate-resilient development in countries of low-to-medium economic development. Many of the more than 200 projects feature agroforestry as an effective means of building resilient livelihoods in rural communities. The scale of support by the Green Climate Fund and other initiatives illustrates how agroforestry is widely seen as offering great potential to adapt an old practice to meet modern needs.

While it is encouraging to see global agreements reached and funds flowing to support ‘green’ initiatives, the World Resources Institute provides a stark reality check, reporting that in 2021 alone over 11 million hectares of tropical forests were felled. Furthermore, over the past 20 years, 11% of the world’s tree cover has been lost. The Bonn Challenge, initiated by Germany and now involving more than 60 countries, is coordinating efforts to restore deforested and degraded landscapes across 350 million hectares by 2030. The precarious state of the world has led to ambitious and laudable initiatives (such as the Green Climate Fund and The Bonn Challenge), yet these initiatives are offset by the relentless pursuit of economic development with its ignored or unintended consequences – for both people and landscapes.

The profound challenges we face need practical solutions that are affordable for smallholders, tailored to the local context, and consistent with the relevant long-term strategies (national and transnational aspirations). The ACIAR Forestry Program has actively supported applied research projects working at the forestry–livelihood nexus for several decades, including much of the research featured in this book. The program invests in research that improves our understanding of how forestry can improve livelihoods of smallholders and their communities. A major focus of recent research has been on exploring how to enhance value chains that have robust economic potential for smallholders and the corresponding industries.

Key insights from applied research

After introducing the purpose and scope of this book (**chapter 1**), we outline the diversity and scale of agroforestry practised by smallholders. Page et al. (**chapter 2**) then explore the domestication of wild tree crops in Melanesia, an area of the South Pacific, as a means of diversifying and enhancing agroforestry for smallholders. The authors say it is already apparent that when smallholder tree growers use improved germplasm, their financial returns, and the wider economic benefits, generally increase. It is, however, difficult to evaluate the impact and value of tree improvement activities in Pacific countries as there are few accurate long-term records of trials. The lack of reliable data also makes it hard to develop financial models to inform growers. Making more reliable data available to growers about the yields and commercial potential of wild germplasm is an essential prerequisite to future progress. Collecting localised data alone will not be enough to aid in promoting the diversification of new tree crops from wild species. Also needed are guidelines that go beyond tree breeding and communicate the process and value of tree domestication in an accessible format that can be easily understood by growers. These guidelines should seek to translate the latest science into practice.

While it is increasingly advocated that successful agroforestry requires a people-centred or 'farmer first' (Chambers et al. 1989) approach, in **chapter 3** Wiset et al. conclude that understanding the concerns and interests of smallholders in relation to forestry projects need not be a difficult or expensive process. Their participatory research approach used a form of 'visualisation' that was a relatively easy process for engaging local people so that they can express their preferences. Their research also highlighted the gendered nature of forestry where men and women of the same community may not necessarily share the same preferences for tree planting and land use, and that these differences, when expressed and understood, can and should be accommodated in the project design stage. Fully engaging local communities in the entire design–management–market process is essential if smallholders are to invest in tree crops and forests with a strong sense of ownership.

Figure 16-1: Smallholders selling produce at a city market

Credit: Digby Race

Understanding the history of a country's economic development and the role of forestry is important for understanding the farming norms and attitudes towards agroforestry today – planting trees on fertile farmland can still trigger mixed and passionate emotions within local communities, both for and against. In **chapter 4**, Mienmany et al. concluded that in the almost 50 years since the Lao People's Democratic Republic was formed, smallholders have experienced dramatic changes in government policy, including a brief period of collectivisation and a largely 'closed' economy, followed by the current influx of considerable foreign investment and the rising influence of neighbouring burgeoning economies. The growing of teak for its world-renowned timber was an early policy-led initiative to encourage smallholders to plant this species on available land and establish a long-term resource for the country. Teak ownership is now distributed across all but the poorest households, although the greatest benefits have tended to accrue to the wealthier households and absentee owners. The common benefit of teak for smallholders is they typically see it as a low-input way to build a 'green savings account' that can be readily drawn upon in future years. However, in recent years more financially rewarding cash crops have emerged, so the planting of teak has retreated to areas where opportunity costs are lower. A shift in paradigm by policymakers is needed so that smallholder forestry is not just seen as a simple reafforestation program but, instead, is viewed carefully to understand the opportunities and risks for smallholder livelihoods.

While economies of scale will always influence the overall profitability of agroforestry, there is a tendency to overlook or understate the risk to livelihoods from agronomic, environmental, economic and social sources, and the resilience offered by mixed farming systems, including agroforestry systems. An important part of assessing the costs and benefits of different options for smallholders is accounting for risk and calculating the value for smallholders when they alter their farming systems. How to balance risk and resilience needs to be part of the advice and support offered to smallholders, so they can make informed decisions. This information also needs to be understood by government policymakers so that support for agroforestry and plantation forestry is not unfairly geared in favour of large-scale and corporate interests at the expense of smallholders. Mienmany et al. found that small-scale industry can be agile and flexible, well suited to providing commercial pathways for the variable production from smallholders. Providing an enabling policy environment for smallholders and their likely allies along the value chain remains an important role for government, if teak grown by smallholders is to remain an integral component of the Lao farming landscape. As prices for teak and alternative crops fluctuate, so too do the opportunity costs and trade-offs. A recent assessment of teak in the province of Luang Prabang (in north-central Laos) suggests that this does not necessarily mean that the net area of trees will shrink, but the location of trees in the landscape may change. Ensuring a fair return for all investing along the value chain is an important influence on the commercial viability of smallholder forestry, as bottlenecks and exploitative monopoly actors increase the risk of smallholders losing out and could dissuade them from investing further in actively managing trees.

Conversely, if local influences are supportive of agroforestry – teak and other species – due to government policy, market prices and supportive norms, then smallholders will readily respond to changing circumstances and opportunities. Demographic change can also influence the take up of agroforestry. For example, in rural areas where the population is declining, and fewer hands are available for cultivation and cropping, the remaining smallholders have sought low-input land uses that can still yield value – for many, growing teak has been an obvious choice.

In neighbouring Vietnam and further afield in Costa Rica, Lo et al. (**chapter 5**) reflect on their lengthy careers fostering smallholder forestry, which, they report, has not always been a straightforward path. Constant development pressures can easily overwhelm safeguards and support for the natural environment, often placing smallholders in an unenviable position of having to find the hidden path to prosperity with sustainability. This tension can flux and wane in any given setting, so investing in applied research alongside smallholders offers, perhaps, a good chance of building their capacity to make informed decisions for themselves, their communities and the surrounding landscape. Some of Lo et al.'s salient advice is to build on local knowledge and practice, rather than introduce untried novel alternatives – favouring a process of continuous learning and improvement over radical change. Also, as commonly reported in other development sectors, outcomes tend to be enduring and positive when long-term and trusted partnerships are established with smallholders and partner organisations. Short-term projects, even with generous support (for example, giving free seedlings to smallholders), can often lead to disappointment and failure to achieve intended outcomes.

Although growing teak is widely seen as a low-input land use by smallholders in Laos, Dieters and Pachas (**chapter 6**) see an opportunity to further increase the efficiency of teak agroforestry systems by reducing the labour required for weeding. Manual weeding is not only labour intensive, but the timing conflicts with periods of high labour demand for other crops and activities. In contrast, thinning and pruning of teak is much more flexible as it can be done either during the dry season, after the annual crops have been harvested, or before the next season's demands arise. The key ways to suppress weeds are effectively burning ground material and establishing a vigorous companion crop – when combined, they will largely suppress weeds in the trees' first growing season. In the subsequent years, weed growth can be reduced by establishing perennial crops in the alleys between tree rows, together with regular visits to remove any weeds before they become established. As the cost of labour increases, using mechanical tools such as a brushcutter becomes more attractive than traditional manual weeding. Another strategy is to reduce the light penetrating the canopy by planting multiple rows of teak close together, rather than single or paired rows, with alley crops planted outside the rows of teak. Reducing the labour requirement for weeding among the teak trees, particularly during busy periods, makes agroforestry more appealing.

Long-term research in Indonesia by Race et al. (**chapter 7**) has found that the economic dynamics that most strongly influence the profitability of smallholder forestry operate at the local and provincial levels. As in other countries, ensuring smallholders can sell into fair and profitable value chains, for all actors, is an important ingredient for a viable long-term industry. As other authors found, it is critically important that government agencies are well connected and streamlined for efficient administration, coordination of support activities and effective regulatory oversight of the value chains used by smallholders. A typical value chain can include growing, harvesting, transporting, processing, manufacturing and retailing. While smallholder forestry often has a focus on timber, agroforestry can also include a range of non-timber forest products (for example, bark, medicinal herbs, fruit and seeds) and, increasingly, novel markets for environmental services (for example, biodiversity, carbon sequestration, ecotourism). Expanding the 'palette' of opportunities for agroforestry beyond timber will open new markets and appeal to a wider range of potential investors – including smallholders, small and large businesses, government agencies, private organisations, and domestic and global markets. This is an exciting frontier for smallholders seeking to access the opportunities from development while remaining faithful stewards of their local environment – perhaps more so for those in remote locations where they face disadvantages with conventional economic geography.

Reimagining rural landscapes when society is experiencing profound changes was also called for in the remote Himalaya of Nepal. KC et al. (**chapter 8**) found that here, too, smallholders are shifting towards less intensive farming and moving to central villages and urban centres. A consequence of this trend is that abandoned and underused farmland is increasingly being covered in forest. The increasing tree cover on farmland is providing unintended opportunities, such as diversifying rural livelihoods and increasing the ecological resilience of rural landscapes. Again, with more trees on former agricultural land, there is scope to explore how a broader range of ecosystem services, such as carbon sequestration, might be valued and lead to payments to rural communities. Low-input and efficient silvicultural options for smallholders are also noted as another area for further research so that the emerging 'new' farm forests can be optimised and valued – both in situ and in added-value or niche industries.

Adopting the philosophy of 'farmer first' is very much what Muthuri et al. (**chapter 9**) describe about their work in Ethiopia, Rwanda and Uganda in eastern Africa. Their findings are based on farmer participatory trials that incorporated the local context and circumstances, leading to a greater understanding of farmer-led agroforestry in the Trees for Food Security project. The strong emphasis on having smallholders actively involved in a range of agroforestry trials enabled learnings to be easily shared and understood, leading to several farmer-generated innovations. The research highlighted the benefits of improving water use, improving silviculture with tree pruning, and applying green manure to improve soil fertility – all leading to better yields and quality. Involving smallholders in the design and management of the varying agroforestry layouts, selection of species and assessment of the results of different options ensured they understood the trade-offs and rewards, and so could more easily translate the options that best suited their livelihoods. At a broader scale, the problem of excessive grazing by livestock due to 'free grazing' in some areas of Ethiopia was more effectively addressed when communities of smallholders were actively involved in the design of locally specific options that reflected their local context. Also, close engagement with smallholders made possible the establishment of 5 rural resource centres and 18 satellite nurseries (under cooperative, group or individual management) across Ethiopia, Rwanda and Uganda. These centres have been invaluable for the production and distribution of quality germplasm of key tree species, as hubs for local training and for demonstrating locally relevant agroforestry options, and for providing farmers opportunities to share experiences with their peers.

Figure 16-2: Farm-grown logs stacked ready for collection

Credit: Digby Race

Applied research across Indonesia by Sudomo et al. (**chapter 10**) found that optimising land use with food crops grown beneath tree crops can lead to an overall increase in food and fibre production. While most food crops are cultivated in open areas, it is common for some tuber species (for example, arrowroot, canna and yam) to be grown under trees with shade between 30% and 70% in community-based agroforestry systems. As a general rule, optimal management of annual and perennial crops in an agroforestry system varies according to the specific biophysical, economic and social conditions, making local knowledge drawn from years of experience and local trials vitally important. Furthermore, we know that the successful management of agroforestry goes beyond just technical expertise – it also involves coordinating and integrating farm work with the myriad of other demands and interests of smallholders – highlighting that optimisation is a complex and ever-changing algorithm. While agroforestry systems are typically more complex than monoculture systems, they have the potential to yield more biomass, be more resilient (given their ecological and enterprise diversity), and be affordable and manageable for smallholders.

Although varying by country and locality, it is estimated that nearly 80% of people in the South Pacific are smallholders managing farms with mixed-species or agroforestry systems and little access to distant markets. Working closely with smallholders and other partners along the value chain, Wallace et al. (**chapter 11**) discuss their research in adding value to new agroforestry products. The logic is to process and add value to available products by stabilising fresh products (for example, preserving), increasing the shelf life and enhancing market access – this can add considerable value if processed locally. They used a market-driven approach to identify opportunities for value-added products and found that a well-functioning value chain is critical to business competitiveness and long-term sustainability. They searched for opportunities in the fruit, nut and honey industries, and for opportunities in value-adding and small-scale food processing. They achieved positive outcomes working with smallholders (mostly women) in Fiji, Vanuatu and Solomon Islands. For example, in Solomon Islands, women increased the value of various species of nuts (such as *Canarium* and *Terminalis*) by being able to sell value-added nuts at about a threefold increase in price compared to selling fresh or raw nuts. In Fiji, training enabled smallholders to add value to their fresh produce and progress to making commercial sales of chutneys and jams. The importance of this enterprise development was highlighted during the COVID-19 pandemic when restrictions caused many to lose their paid jobs – being able to profitably sell their limited produce was a vital source of income for these smallholders.

In parallel research, Wallace et al. (**chapter 12**) found that, when commercialising agroforestry products, understanding the value chain is important for determining who benefits and how the benefits are shared. For example, in Papua New Guinea they found that women were more likely to sell produce at the 'farm gate', whereas men were more likely to have access to means of transport and so could sell produce at the 'factory door', thereby achieving a higher price. Also, women tended to trade in informal markets, whereas men often traded in formal markets (for example, through contracts with agents or companies). Initiatives seeking to achieve greater gender equity and improve wellbeing need not just look at decision-making and operations on the farm – they should also follow the value chain to fully understand how the products from agroforestry generate income and how this is apportioned to different people, particularly smallholders. An important and concerning, if unintended, consequence occurs when efforts to formalise the commercial pathways for smallholders actually disadvantage women who rely on local informal markets (for example, selling to neighbours or within their village).

The pioneering work by Reid (**chapter 13**) to design, develop and adapt the farmer-centred Master TreeGrower training program highlights the enduring value of building the capacity and confidence of smallholders, so they in turn can design and develop agroforestry systems that work best for their livelihoods. Of course, optimal agroforestry varies throughout the world due to a mix of global and local influences which are interpreted differently by individual smallholders. So, advocating for a uniform model or template of agroforestry to be promoted globally makes little sense. Building the capacity of smallholders to critically analyse their situation, the local context and the corresponding opportunities is most likely to ensure development initiatives lead to positive and sustainable outcomes. Consistent with the theory of 'farmer first' (Chambers et al. 1989), the Master TreeGrower program empowers smallholders to learn from their neighbours and others with local experience (for example, processors), and develop their own approach to agroforestry that is optimal for their livelihood. Reid reports that the key to the success of the Master TreeGrower program is that it reinforces the importance of smallholders to make their own management decisions, with industry, non-government organisations, government agencies and other organisations being either supporters of what smallholders decide or consumers of what smallholders produce.

Drawing on years of combined research in a variety of contexts, Fisher et al. (**chapter 14**) reflect on their more recent work in Papua New Guinea. They found that top-down delivery of tree-based projects is often the default *modus operandi* unless a farmer-centred approach is explicitly part of the design. Understanding why smallholders may accept or reject a technology, such as an agroforestry project, is more useful than simply searching for adopters of a given technology. Even within a single community, it can be unrealistic to expect that most people will want to develop the same type of agroforestry or will want the same support. Being more analytical about why different examples of agroforestry or forest management appeal to different smallholders within a village will enable program managers or project leaders to design a more effective project. For example, male and female smallholders may prefer different species; older and younger smallholders may allocate their labour differently; and smallholders with access to machinery can gain access to different markets. Acquiring a deep understanding of what works may take a little extra effort and time, such as spending more time in discussion with communities and observing their daily activities and seasonal variations.

Figure 16-3: Women from East New Britain, PNG, using mechanical nut crackers for the first time

Credit: Emma Kill

Even when members of a community express initial interest in a new project, Fisher et al. caution that it may not mean they will eagerly participate in subsequent activities or adopt the recommended practice – they may be gathering information and observing those who choose to adopt the new practice, before deciding whether or not to join the project. For those smallholders that choose to adopt the recommended practice, the project team should be mindful to allow smallholders to adapt or experiment with the practice so that they can incorporate what they have learned to best suit their situation. After all, few members of the project team are likely to fully appreciate the burdens and risks faced by smallholders, so it can be difficult to grasp the extent to which an innovation might benefit an individual smallholder.

The complex outcomes of commercialising agroforestry or small-scale forestry is discussed further by Keenan (**chapter 15**) who has explored this at a larger scale. Corporate investment and government policies to expand commercial forestry often favour large-scale investment in technology and machines, standardised tasks and processes with hierarchical and 'scientific' management and the ensuing spatial orderliness, but this invariably disadvantages and understates the potential of smallholder forestry with its perceived diverse, messy and variable production. Refreshingly, Keenan argues that, in the right context, it is possible for partnerships between rural landowners, timber processors and investors to successfully link both options. Business models can be collaborative when they involve close working partnerships and the costs and benefits are shared fairly among all involved, from smallholder growers, agents and brokers, to processors and manufacturers, through to retailers – everyone who is a 'shareholder' in the value chain. Whatever the business arrangement, all partnerships should be based on sound financial analysis, good technical information, transparent agreements that clearly assign the roles, responsibilities and ownership (or rights) of different assets (land and trees), and should fairly apportion risks and rewards for each party. At a global level, the continuing interest in achieving sustainable development and the increasing scrutiny of corporate behaviour favours responsible partnerships that lead to smallholders being fairly rewarded for their efforts while encouraging sustainable production practices, such as agroforestry.

Figure 16-4: Smallholders are skilled at providing for household needs and selling in commercial markets.

Credit: Digby Race

Emerging lessons and guiding principles

Some of the rich tapestry of opportunities of agroforestry and how it is practised throughout the tropical world – in Africa, Asia, Central America and the Pacific region – are presented in this book. It was never intended for this book to provide a comprehensive catalogue of the broad diversity of agroforestry practices; rather, we sought to capture the experiences and insights of people who have invested many years of their professional careers working with smallholders and other partners to optimise agroforestry, wherever it may occur in the tropics and whatever its context. We deliberately looked for experiences along the agroforestry value chain (growing, harvesting, processing and manufacturing), for timber and non-timber forest products, for experiences from smallholders and their partners, and for technical practices and policy responses. What we found, and share here, are lessons and ideas about whether we can collectively make agroforestry a better fit and a bigger part of smallholder livelihoods and the landscapes that smallholders manage.

From this collection, 8 guiding principles emerge that may be useful for informing thinking about agroforestry – its people, practices and policies. These principles should be evident if agroforestry is to be a common land use that supports the prosperity of smallholders and the sustainability of their landscapes. These principles are summarised as follows:

1. **Blended knowledge:** Incorporate current science and innovation to inform smallholders about a range of technology options (for example, improved germplasm, species mix, silvicultural options, value adding) and the changing context (for example, markets, opportunities costs and efficiencies, evolving corporate and community expectations), so that they are able to adapt or choose alternatives in response to a changing world. Contemporary science should complement local knowledge and experience to create a blended or fusion of knowledges.
2. **Local understanding:** Carefully analyse perceived opportunities for agroforestry through the lens of affordability and appropriateness, so that they match the capacity of smallholders and the local context. Characteristics and available resources can vary considerably between districts, countries and regions, so analysis of localised information is essential. Even within a single village, the livelihoods of smallholders are rarely the same, so optimising agroforestry will need to allow for a similar degree of variation.
3. **Secure tenure:** Recognise and secure the investment made by smallholders, which often means ensuring they have secure tenure or rights to the agroforests they manage. Even if they do not have legal ownership or tenure of the land (in many parts of the tropical world, smallholders may not have formal private ownership as it is understood elsewhere), they can still have secure rights, making investment in long-term land use, such as agroforestry, more appealing to them.
4. **Fair markets:** Make sure there are profitable and reliable markets that generally provide a fair return for smallholders and other participants along the value chain. While there may be seasonal demand, supply and price fluctuations, markets may still be reliable, thereby encouraging investment in long-term land-use practices, such as agroforestry. The value chain should afford all participants opportunities, whatever their role, if they are to be regular contributors and receive the anticipated benefits.

5. **Leading smallholders:** Encourage capable and confident smallholders, who have the knowledge, skills and networks with information from experienced peers. This is important if agroforestry is to reflect a 'farmer first' or grassroots initiative. Ensuring smallholders are closely engaged in the research and development process for agroforestry is likely to improve the research itself (for example, ensure it is appropriate to the local context) and provide a firm pathway for translating knowledge into practice. This may mean giving smallholders the opportunity to communicate in ways that are most comfortable for them (for example, via their language, their discussion, their ideas). They could even lead the development, rather than having to adopt or participate in a process designed by outsiders.
6. **Trusted partners:** Choose partner organisations who are prepared to listen, advise and support the aspirations of smallholders. Linking smallholders to viable markets often requires a catalyst, coordinator, technical adviser, researcher or the creation of a financial mechanism (agreement) – all important roles that can be fulfilled by capable and supportive partners.
7. **Policy precision:** Facilitate a policy environment that creates an efficient regulatory process and a supportive point of contact between government and smallholders. This will be more effective than policies that use blunt instruments and short-term targets of mass tree planting. Policy that is fit for purpose can accommodate the context and goals of the target audience, so that the aspirations of smallholders are aligned with the policy intent. A policy focused on simply establishing a predetermined area of forest, rather than on enhancing smallholders' livelihoods, risks leaving them with an expensive and unwanted legacy.
8. **Supportive networks:** Invest in a reinforcing loop of current and localised information with the support of partner organisations to progressively build smallholders' capacity for agroforestry. As smallholders grow in confidence over time, they will respond to changes in their circumstances and in the surrounding context. Sometimes change does not follow a consistent or predictable trajectory, so be wary of short-term incentives (for example, free seedlings) that may stimulate short-term enthusiasm, but not attract the underlying commitment of smallholders needed for the desired long-term outcomes.

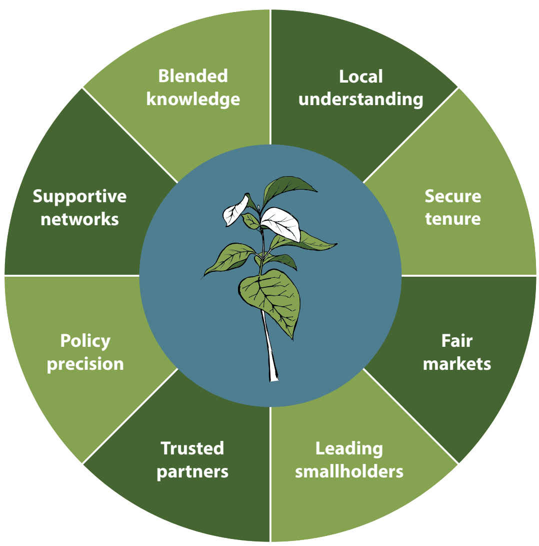

Figure 16-5: Principles for optimising the context for agroforestry

A final word, a vision and … thanks

Is there really an end point or target for agroforestry, or should we see ourselves as contributing to continuous evolution and expansion of knowledge about its practice? After all, farmers come and go, landscapes change, markets are fickle and extreme weather more likely, but the tree of life continues to grow, all the while shedding fruit and leaves. Occasionally, the germination of its seed begins the growth of a new tree or, more philosophically, new ideas emerge. Perhaps it is an enigma to be pondered but never fully understood. What is evident after reading the stories presented in this book is that agroforestry in the hands of experienced and knowledgeable smallholders, supported by capable and trusted partners, makes a vital contribution towards sustaining us all.

I am immensely grateful to the array of talented authors who have shared their experiences, insights and lessons, much of it acquired through many years of dedicated professional work alongside smallholder communities and other partners.

The next time you enjoy local farm produce, shelter among the trees on a healthy farm or see the thoughtful management of a prosperous landscape, be thankful for the smallholders who diligently labour away to sustain their patch of the world. We now know that we can do better by investing in local people, partners, industries and supportive institutions, so that they can create the agroforestry that successfully links smallholder livelihoods, economic development and environmental sustainability. In doing so, we can achieve a 'win, win, win' for us all.

References

Chambers R, Pacey A and Thrupp LA (eds) (1989) *Farmer first: farmer innovation and agricultural research*, Intermediate Technology Publications, London, England.

Intergovernmental Panel on Climate Change (IPCC) (2021) *Climate change 2021: the physical science basis – summary for policymakers*, Working Group 1 contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Switzerland.

——(2022) *Climate change 2022: impacts, adaptation and vulnerability – summary for policymakers*, Working Group 2 contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Switzerland.

——(2023) *AR6 synthesis report: climate change 2023,* synthesis report for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, Switzerland.

Appendix 1: Contributors

Editors

Digby Race, The University of the South Pacific, Suva, Fiji
Gib Wettenhall, em PRESS Publishing, Victoria, Australia

Authors

Authors are listed alphabetically by surname.

Chapter 1: Overview of smallholders' livelihoods and forestry

Digby Race, The University of the South Pacific, Suva, Fiji

Chapter 2: Domesticating wild tree crops in the South Pacific

John Doran, CSIRO Australian Tree Seed Centre, Canberra, Australia

Paul Macdonell, University of the Sunshine Coast, Maroochydore, Queensland, Australia

Tony Page, University of the Sunshine Coast, Maroochydore, Queensland, Australia

Lex Thomson, University of the Sunshine Coast, Maroochydore, Queensland, Australia

Chapter 3: Recognising different interests among local stakeholders: case studies from the Philippines and Papua New Guinea

Robert Fisher, University of the Sunshine Coast, Maroochydore, Australia; The University of Sydney, Camperdown, Australia

Roger Tripoli, Visayas State University, Baybay City, Leyte, The Philippines

Nathan Wampe, Ramu Agri Industries Ltd, Lae, Morobe Province, Papua New Guinea

Kanchana Wiset, University of the Sunshine Coast, Maroochydore, Australia

Chapter 4: Understanding the dynamics of smallholders growing teak in northern Laos

Peter Kanowski, Australian National University, Canberra, Australia

Soytavanh Mienmany, Australian National University, Canberra, Australia

Hilary Smith, Australian National University, Canberra, Australia

Chapter 5: Reversing massive deforestation in Vietnam and Costa Rica

Ken Gallatin, independent forester, Costa Rica

Duc Minh Lo, Southern Cross University, Son La, Vietnam

J Doland Nichols, Southern Cross University, Lismore, Australia

Chapter 6: Developing appropriate teak-based agroforestry for smallholders in northern Laos

Mark Dieters, The University of Queensland, Brisbane, Australia

Nahuel Pachas, Queensland Department of Agriculture and Fisheries, Nambour, Australia

Chapter 7: Exploring opportunities for Indonesia's social forestry agenda

Achmad Rizal Hak Bisjoe, National Research and Innovation Agency, Indonesia
Wahyudi Isnan, National Research and Innovation Agency, Indonesia
Nurhaedah Muin, National Research and Innovation Agency, Indonesia
A Muktasam, University of Mataram, Mataram, Indonesia
Digby Race, The University of the South Pacific, Suva, Fiji
Dede Rohadi, Ministry of Environment and Forestry, Jakarta, Indonesia
Mark Schmidt, Trees4Trees, Semarang, Indonesia
Hugh Stewart, University of the Sunshine Coast, Maroochydore, Australia
Aneka Prawesti Suka, Ministry of Environment and Forestry, Bogor, Indonesia
Depi Susilawati, Australian National University, Canberra, Australia

Chapter 8: Matching farms and forests to a changing demographic in the Middle Hills of Nepal

Robert Fisher, University of the Sunshine Coast, Maroochydore, Australia; The University of Sydney, Camperdown, Australia
William Jackson, University of the Sunshine Coast, Maroochydore, Australia
Bhawana KC, University of the Sunshine Coast, Maroochydore, Australia
Digby Race, The University of the South Pacific, Suva, Fiji

Chapter 9: Developing 'farmer first,' locally adapted agroforestry in eastern Africa

Joel Buyinza, The University of Adelaide, Urrbrae, Australia; National Forestry Resources Research Institute, Kampala, Uganda
Sammy Carsan, World Agroforestry, Nairobi, Kenya
Athanase Rusanganwa Cyamweshi, Rwanda Agriculture and Animal Resources Development Board
Abayneh Derero, Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia
Charles Galabuzi, National Forestry Resources Research Institute, Kampala, Uganda
Wondwossen Gebretsadik, Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia
Abrham Girmay, World Vision Ethiopia
Kiros Hadgu, World Agroforestry, Addis Ababa, Ethiopia
Ruth Kinuthia, World Agroforestry, Nairobi, Kenya; One Acre Fund, Kakamega, Kenya
James Kung'u, African Network for Agriculture, Agroforestry and Natural Resources Education, Kenya; Kenyatta University, Nairobi, Kenya
Anne Kuria, World Agroforestry, Nairobi, Kenya
Maimbo Malesu, World Agroforestry, Nairobi, Kenya
Jeremias Mowo, World Agroforestry, Nairobi, Kenya
Alex Mugayi, World Vision Rwanda
Athanase Mukuralinda, World Agroforestry, Kigali, Rwanda
Catherine Muthuri, World Agroforestry, Nairobi, Kenya
Jean Damascene Ndayambaje, Rwanda Agriculture and Animal Resources Development Board, Rubona, Rwanda
Caroline Njoki, World Agroforestry, Nairobi, Kenya
Judith Oduol, World Agroforestry, Nairobi, Kenya; United Nations Economic

Commission for Africa, Addis Ababa, Ethiopia
Clement Okia, World Agroforestry, Kampala, Uganda; Muni University, Arua, Uganda
Immaculate Sekkito, World Vision Uganda
Fergus Sinclair, World Agroforestry, Nairobi, Kenya
Phillip Smethurst, CSIRO, Australia
Shiferaw Tadesse, Bako Agricultural Research Center, Ethiopia
Assefa Tofu, World Vision Ethiopia
Awol Toib, Addis Ababa University, Ethiopia

Chapter 10: Improving community-forest productivity in the arid regions of Nusa Tenggara islands and central Java, Indonesia

Muhammad Hidayatullah, Ministry of Environment and Forestry, Mataram, Indonesia
Dewi Maharani, National Research and Innovation Agency, Cibinong, Indonesia
Ryke Nandini, National Research and Innovation Agency, Cibinong, Indonesia
Aulia Perdana, CIFOR-ICRAF, Bogor, Indonesia
Aris Sudomo, National Research and Innovation Agency, Cibinong, Indonesia
I Wayan Widhana Susila, National Research and Innovation Agency, Cibinong, Indonesia

Chapter 11: Commercialising agroforestry to broaden the market share for smallholders in the South Pacific

Cherise Addinsall, Southern Cross University, Lismore, Australia
Chris Cannizzaro, Griffith University, Queensland, Australia
Luke Fryett, Bula Coffee, Fiji
Kevin Glencross, Southern Cross University, Lismore, Australia
Wayne Hancock, Southern Cross University, Lismore, Australia
Shahla Hosseini-Bai, Griffith University, Queensland, Australia
Kelly Inae, Helping Hands Honey, Papua New Guinea
Craig Johns, The University of Adelaide, Australia
Doni Keli, Jedom, Solomon Islands
Votausi Mackenzie-Reur, Lapita Café, Vanuatu
Paitia Nagalevu, The Pacific Community, Fiji
Birte Nass-Komolong, National Agricultural Research Institute, Papua New Guinea
Raywin Ovah, National Agricultural Research Institute, Papua New Guinea
Bruce Randall, Griffith University, Queensland, Australia
Jimmy Rantes, Department of Industries, Vanuatu
Helen Wallace, Queensland University of Technology, Brisbane, Australia

Chapter 12: Enhancing private-sector-led development of the *Canarium* industry in Papua New Guinea

Graham Ashford, University of the Sunshine Coast, Maroochydore, Australia
Elektra Grant, Griffith University, Queensland, Australia
Dalsie Hannett, The National Agricultural Research Institute of Papua New Guinea
Godfrey Hannett, The National Agricultural Research Institute of Papua New Guinea
Brett Hodges, Griffith University, Queensland, Australia

Shahla Hosseini-Bai, Griffith University, Queensland, Australia
Craig Johns, The University of Adelaide, South Australia, Australia
Kim Jones, Cropwatch Independent Laboratories, Alstonville, Australia
Emma Kill, Griffith University, Queensland, Australia
Birte Komolong, The National Agricultural Research Institute of Papua New Guinea
Simaima Kapi Ling, The National Agricultural Research Institute of Papua New Guinea
Tio Nevenimo, The National Agricultural Research Institute of Papua New Guinea
Bruce Randall, Griffith University, Queensland, Australia
Theo Simos, The University of Adelaide, South Australia, Australia
Carson Waaii, The National Agricultural Research Institute of Papua New Guinea
Helen Wallace, Queensland University of Technology, Brisbane, Australia

Chapter 13: Becoming masters of their trees: experiences of the Master TreeGrower training program in Australia, Africa, Asia and the Pacific

Rowan Reid, Australian Agroforestry Foundation, Birregurra, Victoria, Australia

Chapter 14: Using extension based on action research in developing tree-based programs for smallholders in Papua New Guinea

Grahame Applegate, University of the Sunshine Coast, Maroochydore, Australia
Robert Fisher, University of the Sunshine Coast, Maroochydore, Australia; The University of Sydney, Camperdown, Australia
Micah Scudder, University of the Sunshine Coast, Maroochydore, Australia
Nathan Wampe, Sime Darby Plantation Berhad, Papua New Guinea

Chapter 15: Forming smallholder–industry partnerships to boost reforestation and wood supply

Rodney J Keenan, The University of Melbourne, Australia

Chapter 16: Revealing insights into smallholders' livelihoods and forestry in the tropics

Digby Race, The University of the South Pacific, Suva, Fiji